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BUILDING STONES OF CENTRAL TEXAS

By

VIRGIL E. BARNES, RAYMOND F. DAWSON,
and
GEORGE A. PARKINSON

Bureau of Economic Geology
Bureau of Engineering Research

(Issued July 17, 1947).

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

Enchanted Rock, Llano and Gillespie counties, Texas.

FOREWORD

In 1933 the Bureaus of Economic Geology and Engineering Research of The University of Texas initiated a joint project to examine and report upon the building stones of a portion of central Texas, an area in which there are more types and a greater abundance of building stones than anywhere else in the State, and possibly than in an equal area anywhere in the United States. Since its inception, the work has been progressing as time and opportunity permitted.

Mr. C. L. Baker, of the Bureau of Economic Geology, and Mr. G. A. Parkinson, of the Bureau of Engineering Research, spent several months during 1933 and 1934 making an examination of the building stone deposits and collecting samples for the physical tests. Additional samples were collected by Mr. Parkinson during 1935 and 1936. V. E. Barnes began petrographic and geologic work in connection with the bulletin in 1937.

The division of work by the authors is as follows: R. F. Dawson made the absorption tests, determined the specific gravities, conducted the durability tests, and wrote the chapter on physical testing. G. A. Parkinson collected the samples, prepared polished samples, prepared samples for the various tests, performed the crushing tests, and made thin sections for petrographic study. V. E. Barnes made notes on the geology and location of the deposits, made the petrographic examination, and prepared the text and most of the illustrations.

Manuscript for this report was approaching completion immediately prior to the outbreak of World War II. Due to disruption of normal activities and dislocation of the printing industry occasioned by the war, it has been necessary to delay publication of the report and modify its plan. Color illustrations of some of the building stones were eliminated because of prohibitive cost, and other modifications were made.

John T. Lonsdale,
Director, Bureau of Economic Geology

W. R. Woolrich,
Director, Bureau of Engineering Research

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PART I

Virgil E. Barnes

INTRODUCTION

The area covered by this report includes portions of only 10 average-sized counties in a State having 254 counties. It was chosen for examination because of the great variety and amount of building stone available in a limited area and because the district is rapidly becoming a quarrying center. It was not feasible to cover the whole State systematically at this time even though other areas have abundant building stone deposits. In Trans-Pecos Texas there are numerous types of building stone, many of which are in large deposits. Some of these deposits, such as the lithified volcanic ash of the Fort Davis area, are unusual and have colors and other physical properties which make them highly desirable as building stone. Throughout the Pennsylvanian outcrop area of north-central Texas there are many limestones, some of which undoubtedly are excellent building stones. Also not discussed are the dolomites of the Permian and the greater portion of the Cretaceous limestones of the Edwards Plateau. This publication is limited to a portion of central Texas and is not to be construed as covering the building stones of the entire State.

An 8-page bulletin by Nash[1] on the granites of central Texas was published in 1917. Mr. Parkinson performed the tests which were included in that bulletin and since that time has been active, as opportunity offered, in making a more detailed examination of the building stones of the State and disseminating the information to those who were interested. Very little information has been published on Texas building stones except the small publication on Texas granites already noted and a short paper by Raymond F. Dawson entitled "Texas Natural Building Stones and Their Development," The Journal of Architecture, Engineering and Industry, vol. 3, no. 3, pp. 2–5, March, 1941.

The geology of the area will be very briefly summarized in order to give the reader a picture of the area as a whole. The rocks of central Texas are divisible into three groups, namely, pre-Cambrian, Paleozoic, and Mesozoic. All three groups contain building stones of great economic importance.

The pre-Cambrian group is confined to Llano, western Burnet, eastern Mason, northern Gillespie, northwestern Blanco, southern San Saba, and southeastern McCulloch counties. It is one of the oldest groups of rocks exposed in Texas and is composed of at least three major groups of rock—schists, gneisses, and granites. Comstock[2] named the first series the Packsaddle schist and the second series the Valley Spring gneiss. Paige[3] redefined and applied these names to the metamorphic rocks which he mapped in the Llano-Burnet area. He divided the granites into fine-grained granites and coarse-grained granites.

The Packsaddle schist and the Valley Spring gneiss are the oldest series of rock yet recognized in the region. The Packsaddle series was originally bedded sedimentary rocks composed of a series of shales, sandy shales, carbonaceous shales, calcareous shales, impure sandstones, and more or less pure limestones and dolomites. Great thicknessess of these rocks were deposited, and in addition thousands of feet of other rocks were deposited above them of which there is now no record. This rock series was highly folded, faulted, and injected by igneous rocks during a mountain-making movement. During this disturbance, the original character of the sedimentary rocks was altered; minerals

[1]Nash, J. P., Texas granites: Univ. Texas Bull. 1725, 8 pp., 1917.

[2]Comstock, T. B., A preliminary report on the geology of the Central Mineral region of Texas: Texas Geol. Survey, 1st Ann. Rept., 1889, pp. 237–391, 1890.

[3]Paige, Sidney, Mineral resources of the Llano-Burnet region, Texas, with an account of the pre-Cambrian geology: U. S. Geol. Survey Bull. 450, pp. 15–21, 1911.

were destroyed, new ones were formed, and the whole became metamorphosed. The original folding in this area was isoclinal, as is shown by repetition of marble and granite schist bands and by the occasional outcrops of the sharp crests of such folds.

The rocks which were originally limestone and dolomites recrystallized into true dolomitic and calcitic marbles, some of which are excellent white or light-colored building and monumental stones. Others which contained clay or shale as impurities recrystallized into marbles composed, in addition to calcite and dolomite, of diopside, wollastonite, and other minerals of metamorphic origin. These impure marbles are colored various shades of light to dark gray and light green and are more or less banded. They are of use for building and monumental stone.

The rocks which were originally shales, calcareous shales, and sandy shales have recrystallized according to their composition and history into biotite schist, muscovite schist, hornblende schist (amphibolite), talc schist (soapstone), quartz schist, and various other types and mixtures of all these types. These rocks are unsuited for building stones with the exception of some of the amphibolites and soapstones.

The carbonaceous shales have been changed into graphite schist. The flakes of graphite vary considerably in size in different areas, depending upon the degree or intensity of metamorphism and the proximity of intrusions. The graphite schists are not of value for building stones.

The Valley Spring gneiss is predominantly a pink, fine- to medium-grained rock which in general is resistant to weathering. It forms the more rugged areas of the Central Mineral region. Most of the Valley Spring gneiss probably originated from impure sandstone. The gneisses have not been examined in general with reference to their value as building stone, but the senior author is of the opinion that in this region many masses of Valley Spring gneiss are present which are excellent building stones comparable to gneisses from other areas.

The region is much more complex than is indicated by Paige's generalized mapping. When the area is mapped in detail more than one schist series and more than one gneiss series may be found.

A group of basic igneous rocks was intruded into the schist-gneiss series. According to Paige, these rocks are older than the granites which follow. Some of these basic masses have been completely serpentinized and are usable as building and ornamental stones.

Paige has mapped a series of southeastward-plunging synclines and anticlines in the schist-gneiss series. These open folds are a later cross folding of the already isoclinally folded rocks and are probably related to the intrusion of large granitic masses. Several periods of intrusion are recognized by Stenzel.[4] The oldest of the granites as termed by Stenzel are the Town Mountain granites, named for Town Mountain just north of Llano. These are coarse-grained to porphyritic granites commonly containing large flesh-colored feldspars. His next group is the Oatman granites typically exposed in Oatman Creek southeast of Llano. These are medium-grained, gray to pink, cataclastic granites. His third group is the Sixmile granites typically exposed in quarries near Sixmile, southwest of Llano. These granites are fine-grained, gray, biotite granites. The final intrusions of the area are of opaline quartz-porphyry and felsites. All of these groups except possibly the felsites contain abundant and excellent building stone.

The events transpiring between the last igneous activity and the first deposition of Paleozoic sediments are imperfectly known, but erosion was important since it removed miles of rock. The surface at the advent of Paleozoic sedimentation was somewhat hummocky. The more resistant rocks, such as the gneiss of Niggerhead in Burnet County, stood a few hundred feet above the general level of the country.

The first sediments deposited on this old surface were dreikanters[5] followed by wind-deposited sands. The age of these deposits is presumably Cambrian since they grade upward into marine sandstones containing Upper Cambrian fossils. The thickness of the aeolian sandstone has not

[4]Stenzel, H. B., Pre-Cambrian structural conditions in the Llano region, *in* The Geology of Texas, Vol. II, Structural and economic geology: Univ. Texas Bull. 3401, pp. 74-79, 1934 [1935].

[5]Barnes, V. E., and Parkinson, G. A., Dreikanters from the basal Hickory sandstone of central Texas: Univ. Texas Pub. 3945, pp. 665-670, 1939 [1940].

been determined as yet but is included in the 250-foot maximum of sandstone mentioned by Paige[6] as comprising the lower part of the Cambrian. Due to irregularities of the pre-Cambrian surface, the Hickory sandstone is now known to be absent in some small areas and to range up to at least 335 feet, a thickness computed by Cloud[7] in the Moore Hollow area of the Riley Mountains of Llano County. Revision of the Cambrian nomenclature has been made since this paper was sent to the press. Unfortunately, changes could not be made in the plate and figure illustrations to conform to corrections made in the text. The divisions now [1947] recognized are as follows: references are to the first appearance of the name in literature:

Upper Cambrian
- Wilberns formation[6]
  - San Saba limestone member[8]
  - Pedernales dolomite member[9, 10]
  - Point Peak shale member[9, 10]
  - Morgan Creek limestone member[9, 10]
  - Welge sandstone member[9, 10]
- Riley formation[7]
  - Lion Mountain sandstone member[11]
  - Cap Mountain limestone member[6]
  - Hickory sandstone member[6]

Sandstone from the Hickory sandstone member of the Riley formation has been used for building stone. This member outcrops, with some interruptions by faulting and overlap, around the central pre-Cambrian area, and each succeeding member of the Riley and Wilberns formations forms an outcrop more distant from the central pre-Cambrian.

The Cap Mountain limestone member as redefined is somewhat thicker than the 100 to 220 feet reported by Lochman.[12] Cloud[7] computed a thickness for it of 421 feet in the Moore Hollow area of the Riley Mountains of Llano County. This member contains some massive brown to gray, bluff-forming beds which are of value for building stone and for crushed stone.

The Lion Mountain sandstone member of the Riley formation is a glauconitic friable sandstone containing, in the lower part, cross-bedded lenses of limestone composed of trilobites. The Lion Mountain sandstone is of no value for building stone.

The Welge sandstone member of the Wilberns formation is a nonglauconitic brown sandstone about 24 feet thick in northwestern Gillespie County which becomes thinner and somewhat glauconitic in Burnet County. The name Welge is from a land survey in Gillespie County in which the sandstone outcrops. A typical section of the Welge sandstone is exposed on Squaw Creek, near the south border of Mason County. The Welge sandstone has not been tested for its qualities as a building stone.

The Morgan Creek limestone member of the Wilberns formation is a persistent, fine- to medium-grained glauconitic limestone extending throughout the area. It is gradational at the base into the Welge sandstone and at the top into the Point Peak shale. Typical exposures of this limestone, named by Bridge,[12a] are present along Morgan Creek, in western Burnet County, from which it received its name.

The Point Peak shale member of the Wilberns formation is a thin-bedded, soft, green, calcareous shale well developed in northern Llano County and less well developed in the southern part of the Llano uplift. It was named by Bridge[12a] from a typical exposure on Point Peak, Llano County.

The Pedernales dolomite and San Saba limestone members are roughly equivalent. The San Saba limestone, which is sublithographic to fine grained and glauconitic, is well developed in McCulloch, Mason, and Gillespie counties, and the fine- to coarse-grained Pedernales dolomite is well developed in Blanco, Burnet, and Llano counties. The San Saba limestone was named by Bridge[12a] from a typical

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[6]Paige, Sidney, *op. cit.*, p. 23.

[7]Cloud, P. E., Jr., Barnes, V. E., and Bridge, Josiah, Stratigraphy of the Ellenburger group in central Texas—a progress report: Univ. Texas Pub. 4301, pp. 133, 154–155, 1943 [June, 1945].

[8]Dake, C. L., and Bridge, Josiah, Faunal correlation of the Ellenburger limestone of Texas: Bull. Geol. Soc. Amer., vol. 43, p. 729, 1932.

[9]Barnes, V. E., Gypsum in the Edwards limestone of central Texas: Univ. Texas Pub. 4301, p. 37, 1943 [January, 1944].

[10]Howell, B. F., et al., Correlation of the Cambrian formations of North America: Bull. Geol. Soc. Amer., vol. 55, 1944.

[11]Bridge, Josiah, The correlation of the Upper Cambrian sections of Missouri and Texas with the sections in the Upper Mississippi Valley: U. S. Geol. Surv. Prof. Paper 186, pp. 233–234, 1936.

[12]Lochman, Christina, Upper Cambrian faunas of the Cap Mountain formation of Texas: Jour. Pal., vol. 12, pp. 72–85, 1938.

[12a]Bridge, Josiah, Correlation of early Paleozoic sections in central and western Texas (abst.): Bull. Geol. Soc. Amer., vol. 51, pp. 1921–1922, 1940. (The names Morgan Creek limestone, Point Peak shale, and San Saba limestone are not given in the abstract but were presented orally.)

exposure near Camp San Saba, McCulloch County. The Pedernales dolomite is named from Pedernales River in Blanco County, and the type section is upstream from Johnson City.

The Wilberns formation contains a varied lithology and wide number of rock types suitable for building stone. The Morgan Creek limestone member contains good gray limestones suitable for building stone. The Point Peak shale contains locally edgewise conglomerate of value for decorative stone. It also contains locally massive stromatolite marbles of value for building stone. The San Saba limestone member contains extraordinarily large stromatolite marbles, and marbles which contain spherical bodies *(Girvanella)* about half an inch in size. This member also contains some edgewise conglomerates. The Pedernales dolomite contains faint pink and gray dolomite which should be of value as a building stone.

The Lower Ordovician rocks of central Texas have been described and divided into formations and members since this paper was set in type.[13] These rocks are part of the Ellenburger limestone of Paige, which has been revised to Ellenburger group and restricted to beds of Lower Ordovician age. Following is a list of the formations, members, and facies now [1947] recognized in the Ellenburger group:

- Lower Ordovician
  - Ellenburger group
    - Honeycut formation
    - Gorman formation
      - calcitic facies
      - dolomitic facies
    - Tanyard formation
      - Staendebach member
        - calcitic facies
        - dolomitic facies
      - Threadgill member
        - dolomitic facies
        - calcitic facies

The Ellenburger group attains its maximum known thickness of approximately 1820 feet in the vicinity of Johnson City, Blanco County. From there it thins west and north by truncation of the upper beds, being only 970 feet thick along Llano River in western Mason County and slightly over 800 feet thick in McCulloch County.

The Tanyard formation includes between 518 and 658 feet of dolomite and limestone and is divided into two members. The lower or Threadgill member ranges from 313 feet thick in the western to 91 feet thick in the eastern part of the uplift. As a general rule the Threadgill member is principally or wholly limestone in the west, grading eastward to the dolomitic facies and showing such abrupt lateral transitions from limestone to dolomite that it is commonly difficult to determine whether a given contact is a lateral transition, a collapse contact, or a fault. The limestones of the Threadgill member are generally non-cherty, and the dolomites are only locally cherty. Much of the better quality stone of the Ellenburger is present in the Threadgill member.

The upper or Staendebach member of the Tanyard formation ranges between 205 feet thick in the western part of the Llano uplift to 456 feet in the eastern part. As a rule the upper one- to two-thirds of the Staendebach member is limestone in the northeastern part of the Llano region and in the Riley Mountains of Llano County, but in the southeast and west, dolomite predominates and limestone is rare or absent. In general the Staendebach member is highly cherty and of little value as a building stone.

The Gorman formation where not thinned by post-Ellenburger truncation includes between 426 and 498 feet of dolomite and limestone. For the most part the Gorman formation is predominantly dolomitic in the lower part and calcitic above; but measurements show that the dolomitic facies ranges from about 230 to 81 feet thick, and perhaps thinner, whereas the calcitic facies ranges from about 393 to 237 feet thick. A sequence of pure, usually thick-bedded limestone which should be of value as a building stone occurs in the top 40 to 60 feet of the Gorman formation. Many of the dolomites of the lower portion of the Gorman formation are microgranular, variegated, and when polished very attractive.

The Honeycut formation varies in thickness from a known maximum of 678 feet

[13]Cloud, P. E., Jr., Barnes, V. E., and Bridge, Josiah, *op. cit.*, pp. 133–161.

in Honeycut Bend, Blanco County, thinning by truncation westward to a feather edge, and disappearing entirely in the western part of the uplift. Three units of the Honeycut formation are recognizable in Honeycut Bend, but not enough work has been done to determine if it is feasible to map them throughout the outcrop area. The lower unit is an alternation of limestone and dolomite beds, the middle unit is predominantly microgranular dolomite, and the upper unit is predominantly limestone. Only the upper unit appears to be suitable for building stone.

Following the Lower Ordovician and before Devonian time, erosion truncated the Ellenburger rocks. No outcropping Silurian rocks have as yet been found in the Llano region, but outcropping Devonian rocks have recently been reported for the first time.[13a] The Devonian rocks so far seen are of no value for building stone.

The next rocks deposited are of Mississippian age and from the base upward include the Ives breccia, the Chappel limestone, and the Barnett formation. The Ives breccia, composed of chert and some matrix limestone, is seldom over 18 inches thick and is of no value as a building stone. The Chappel limestone ranges up to about 40 or 50 feet thick, is a brownish-gray to pinkish, somewhat crinoidal limestone, and in its thicker development is mostly preserved in structural sinks. it is possible that a deposit of Chappel limestone may be found which is undisturbed and thickly enough bedded to be of value as a building stone. The Barnett formation is shale around much of the uplift but in Mason County grades laterally into a light-colored, coarse crinoidal limestone which is a very attractive stone.

Rocks of Mississippian age are in places absent, allowing the Marble Falls limestone of Pennsylvanian age to rest directly upon the Ellenburger. Cheney[13b] and Plummer[13c] have divided the Marble Falls limestone into four members, as follows:

Base	Gibbons conglomerate
	Sloan member
	Big Saline member
Top	Lemons Bluff member

The Big Saline member contains some desirable gray limestone which takes an exceptionally fine polish. The Sloan member in places contains dark-colored limestones of value as building stone, and the Lemons Bluff member is a spiculiferous limestone which when leached of lime produces a white, light weight, locally used building stone known as "cotton rock."

The next succeeding formation, the Smithwick shale, is approximately 300 feet thick and is a black shale. In the eastern part of its outcrop area it contains a few sandstone beds suitable for local building. Above the Smithwick shale is the Strawn formation (or group) composed of about 21 units which are mostly sandstones and shale, with some limestone near the top. The most important building stones of this group are the sandstones, including members such as the Shadrick Mill sandstone exposed in the southern tip of Mills County and some of the other sandstone members higher in the section in San Saba County.

Higher Pennsylvanian beds which are present in western San Saba County and in the northern part of McCulloch County contain thin limestone that might be desirable building stones. These were not investigated. A large amount of normal faulting which occurred near the end of the Paleozoic era has destroyed the continuity of the outcrops of the various Paleozoic formations.

In the area of central Texas considered in this publication, Paleozoic rocks younger than Strawn are not preserved, and the next rocks deposited are Cretaceous in age. During Lower Cretaceous time, sedimentation was resumed, and the conglomerates, sands, and limestone of the Travis Peak formation were deposited. This was succeeded by the Glen Rose limestone which is typically composed of thin- to medium-bedded, more or less continuous limestone strata alternating

[13a]Barnes, V. E., Cloud, P. E., Jr., and Warren, L. E., The Devonian of central Texas: Univ. Texas Pub. 4301, pp. 163–177, 1943 [June, 1945].

[13b]Cheney, M. G., Geology of north-central Texas: Bull. Amer. Assoc. Petr. Geol., vol. 24, pp. 65–118, 1940.

[13c]Plummer, F. B., Stratigraphy of the Lower Pennsylvanian coral-bearing strata of Texas. Univ. Texas Pub. 4401, pp. 64–69, 1944 [1945].

with marl or marly limestone. Beds of limestone are present which are of value locally as building stone.

The Walnut clay rests upon the Glen Rose limestone. A limestone lentil supposedly in the Walnut clay, known as the Cedar Park member, is present in western Williamson and northern Travis counties. It has been widely used as a building stone. The Cedar Park member may actually be stratigraphically equivalent to beds defined elsewhere as Glen Rose limestone. The entire thickness of the Walnut clay in this area, including the Cedar Park member and an *Exogyra* clay beneath it, is about 160 feet.

The Comanche Peak limestone is above the Walnut formation. The lower portion of the Comanche Peak limestone is a nodular limestone, and the upper few feet is a well-bedded, soft limestone which has been used very widely in some areas as a building stone.

The Cretaceous rocks so far enumerated were deposited against the Llano uplift, composed of older rocks. Figure 1 is a series of sections in Gillespie County which illustrate the overlap of the Cretaceous onto the Llano uplift. The Travis Peak formation ranges in age from older than the Glen Rose limestone to at least the age of the Comanche Peak limestone and is consequently a shoreward facies of the Glen Rose limestone, the Walnut clay, and the Comanche Peak limestone.

The first Cretaceous formation deposited entirely over the older rocks of the Llano uplift is the flint-bearing Edwards limestone. The Edwards limestone is about 300 feet thick in the Williamson-Travis County area. Locally it contains exceedingly pure limestones which have been used for making lime. It has also been used as a building stone. Thin dolomite beds are rather abundant in the Edwards limestone, and some might be thick enough and pure enough to be used.

Formations from the Edwards limestone upward, listed in order of deposition, are the Georgetown limestone, Grayson marl (Del Rio clay), Buda limestone, Eagle Ford shale, and Austin chalk. The Georgetown may contain some building stone, but in general it is too nodular and impure. The Buda limestone is nodular throughout and is unsuited for building stone. The Austin chalk has been quarried to a limited extent locally, but it is not recommended for general building use. The Austin chalk is the uppermost Cretaceous formation which could possibly be used as a building stone.

Recent deposits of travertine and onyx marble have been noted in the area. Only a few travertine deposits are described in this publication. Other deposits undoubtedly will be found as geologic mapping progresses.

Pre-Cambrian Building Stone

Igneous Group

Granites (Quartz-Bearing Rocks)

Properties

Many discussions of the properties of granite are contained in standard works and textbooks on building stones. There is little need to rewrite this material especially since it is already ably stated elsewhere. Quotation will therefore be freely used in the following discussion of the properties of granites.

Definition.—Granite is a term applied by petrographers to a granular igneous rock composed chiefly of orthoclase (mostly microcline) and quartz. In addition, plagioclase is commonly present in appreciable quantities, and the rock may contain any combination of the three minerals biotite, hornblende, and augite. The central Texas granites are predominantly granites in the petrographic sense. The commercial use of the word granite covers a much wider range of rock types and has included practically every known igneous rock, as well as a fair number of rocks of sedimentary origin. Anderson[14] suggests that for economic convenience the term granite should include all "medium or coarse-grained, light-coloured igneous rocks with an appreciable (say, five per cent) amount of quartz."

Chemical and mineral composition.—Bowles[15] makes the following statements:

> The chemical composition of granite has little economic significance. Many prospective granite-quarry operators wish to have samples of their

[14]Anderson, J. G. C., The granite of Scotland: Mem. Geol. Survey, Great Britain, vol. 32, p. 11, 1939.

[15]Bowles, Oliver, The Stone Industries, McGraw-Hill Book Co., Inc., New York, p. 104, 1936.

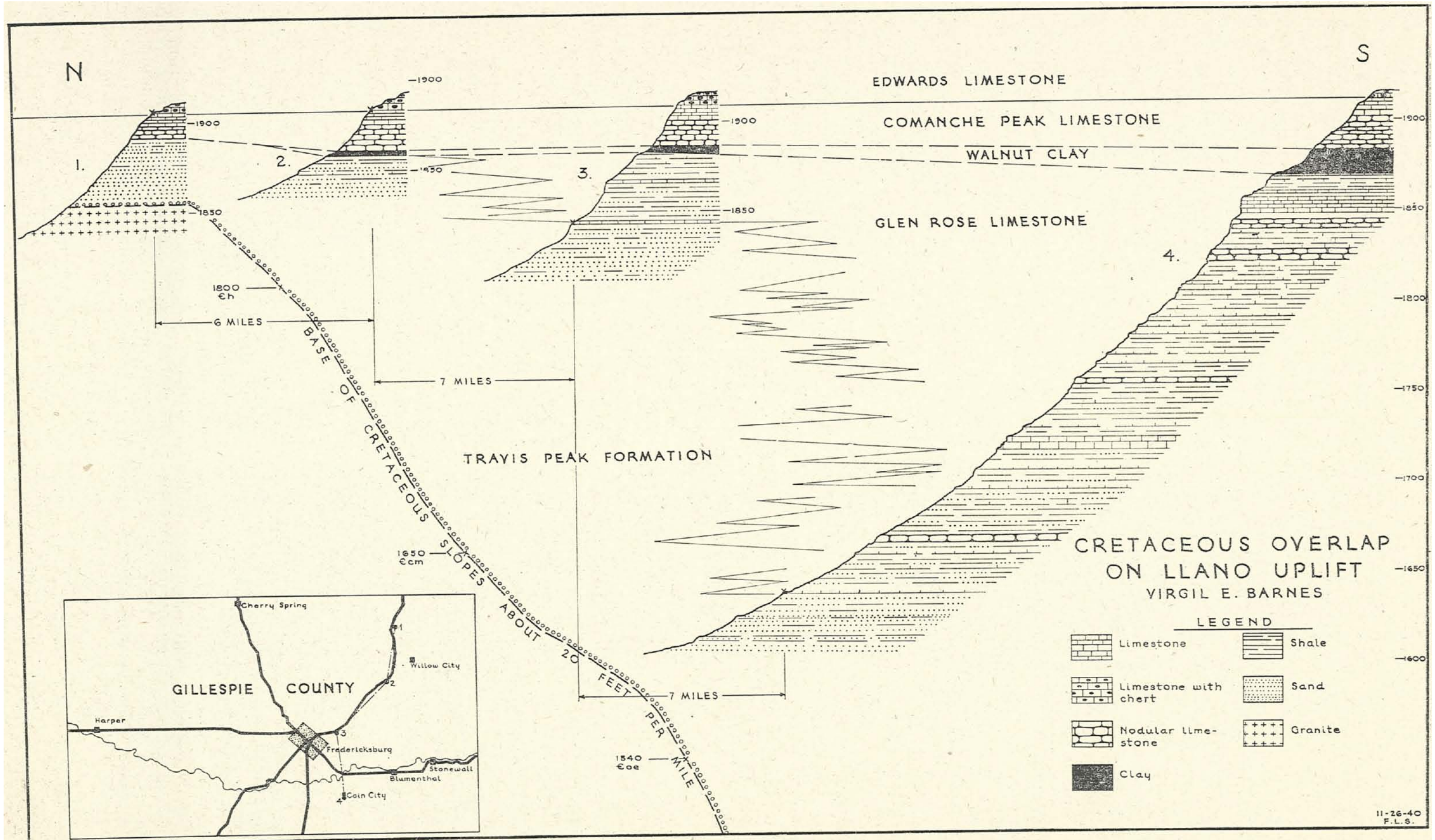

Fig. 1. Sections showing the Cretaceous overlap on the Llano uplift in Gillespie County, Texas.

rock analyzed to determine its quality and probable value, failing to realize that any one element or compound may form constituent parts of several different minerals, some of which may be desirable and some undesirable. For example, an analysis may show a certain amount of iron, but without a very complete analysis and careful calculation the amount of iron present as a constituent of a stable biotite or hornblende or of an unstable and detrimental pyrite or garnet cannot be determined. A chemical analysis, however, may indicate the general composition; thus a high silica content would indicate a high percentage of free quartz. Analysis of a granite is therefore much less important than determination of its mineralogical composition.

Anderson (pp. 12–13) states:

Granites, in the wider sense defined above, usually contain from 55 to 75 per cent of silica. They may be subdivided into: (a) the true granites, of acid composition, in which the silica percentage is over 65; and (b) the quartz-diorites, &c., of intermediate composition, in which the silica percentage varies between 55 and 65. The more acid types are usually relatively richer in the alkalies potassium and sodium (particularly the former) and poorer in lime, iron oxides and magnesia than the intermediate types.

A chemical analysis is, however, of little use in determining the properties of the rock, except in so far as it provides a key to the mineralogical composition. The important constituents of the granitic group of rocks are quartz, orthoclase-feldspar, muscovite-mica, biotite-mica, plagioclase-feldspar, and hornblende. The first two tend to be most abundant in the acid division and the last two in the intermediate. Muscovite-mica is usually found only in highly acid granites. The effect which these minerals have upon the wearing qualities of the rock may next be considered. Quartz is the hardest constituent of granite and also the most resistant to chemical alteration. A good proportion is desirable for building purposes and for setts, but not for roadstones, which it tends to render brittle. The feldspars are also fairly hard but possess a ready cleavage which reduces their strength, although improving the non-skid qualities of setts. The feldspars, particularly plagioclase, are often found in a decomposed state. Plagioclase is frequently "zoned" and the more calcic central portion is sometimes altered, while the sodic margin remains fairly fresh. This is known as "kernel" decomposition and is not serious. On the other hand, any general decomposition of the feldspars, which make up a large percentage of every granitic rock, greatly reduces the value of the latter for all purposes. The micas are distinguished by the readiness with which they cleave into thin flexible flakes. Muscovite-mica is chemically stable, but biotite tends to decompose into the green mineral chlorite, which greatly weakens the rock. Muscovite is a desirable constituent for ornamental and building stones to which it lends a beautiful glittering effect. Both micas are useful in setts as their ready wear keeps the surface rough and non-slippery; too great a proportion, however, tends to weaken the stone. About 10 per cent is said to give the best results (Knight, B. H., Road aggregates: their uses and testing, London, p. 103, 1935). For roadstone a low percentage of mica is desirable. In many granites a majority of the micas are arranged in a particular direction, which may influence the cutting of the stone for monumental purposes. The mineral hornblende, when fresh, toughens the rock and is therefore useful in stone used for constructional work. It is not desirable in any quantity in setts, which it renders slippery when used on a gradient, but it is a very useful constituent of roadstones. Augite is sometimes found in intermediate rocks, although generally in small quantities. It is similar in its effects to hornblende.

Bowles (p. 104) discusses the mineral composition of granites as follows:

Feldspars are the most conspicuous and ordinarily the most abundant minerals in granites. Several kinds usually are present. The potash feldspars (microcline and orthoclase) are the most prevalent and are generally accompanied by small percentages of one or more members of the lime-soda group (the plagioclases). Feldspars may be white, gray, opalescent, reddish, brown, or green, and the prevailing color determines to a large extent that of the rock. Quartz grains may be recognized readily by their glassy luster, absence of cleavage, and uneven fracture surface. Quartz is commonly clear and transparent but may be milky, bluish, yellow (citrine), opalescent, purple, or smoky. Next to the feldspars and quartz, black mica (biotite) is the mineral most abundant in a majority of granites; dark green or black hornblende may be nearly as abundant; and muscovite frequently occurs. When large percentages of biotite or hornblende are present the rock may be nearly black.

Accessory minerals are those that may or may not be present in a rock. When present they are usually in subordinate amounts, and some may be detected only with a microscope. Garnet, zircon, epidote, titanite, magnetite, hematite, limonite, ilmenite, pyrite, apatite, augite, and rutile are the more important accessory minerals of granite, and minute quantities of many others may occur.

Texture.—Bowles (p. 105) states:

The texture of granite signifies the size and arrangement of mineral grains. Uniform grain size usually is demanded in commercial granites for building or ornamental uses. Lack of such uniformity condemns thousands of deposits throughout the world for practical use. Grain size varies greatly in different granites. They accordingly are classed as fine-, medium-, and coarse-grained. Medium-grained granites are those in which the feldspars average about one-fourth inch across.

Some difference of opinion exists on the range of grain size to be included when the classification of fine, medium, and coarse grained is used. Bowles' statement above indicates that medium-grained granite would be one in which the feldspars are about one-fourth of an inch (6 mm.) across. Iddings[16] and Holmes[17] state the grain size on the basis of the average diameter of the crystals composing the rock as follows:

More than 5 mm. = coarse grained
1–5 mm. = medium grained
Less than 1 mm. = fine grained

On the basis of this widely accepted classification an erroneous conception of the grain size of American granites would be obtained. The indication of size as given by Bowles is obviously more suited to a discussion of these granites; therefore, the following arbitrary divisions will be used in discussing Texas granites:

Coarse grained, average diameter more than 8 mm.	.315 inch
Medium grained, average diameter between 4–8 mm.	.158–.315 inch
Fine grained, average diameter less than 4 mm.	.158 inch

Anderson (pp. 13–14) makes the following statements with reference to texture and wearing qualities of granites:

> In a general way, the finer the grain the greater the resistance to all disintegrating agencies. For roadstone in particular the finest-grained rocks are the most suitable. While a fine texture is desirable in setts from the point of view to wear, too fine a grain leads to slippery surfaces. As regards building and monumental work, while a finely crystalline rock may weather better and be less liable to spalling, it is not so desirable from an esthetic point of view. A common texture is that known as porphyritic, in which large crystals occur in a fine-grained groundmass. If the porphyritic crystals (phenocrysts) are large they tend to reduce the value of the rock for roadstone and setts, but porphyritic rocks with small crystals are often very satisfactory. For ornamental work large porphyritic crystals, especially if of a different colour from the groundmass, often have a very striking effect.

Specific gravity, porosity, and strength.—The chapter by R. F. Dawson on physical testing describes these properties of granites and gives the methods of arriving at the value of each property.

The density of granites ranges from about 2.60 (162 lb. per cu. ft.) to about 2.77 (173 lb. per cu. ft.). An average acid granite has a density of about 2.67 (166½ lb. per cu. ft.).

The porosity of average granites ranges between about 0.10 and 0.50 per cent. Much of this porosity is of microscopic size situated both along grain boundaries and within grains.

The crushing strengths of granites vary widely, ranging mostly between 20,000 and 30,000 pounds per square inch. Buckley[18] gives a range for the Wisconsin granites of 15,000 to 43,973 pounds per square inch. The Texas granites range between 16,500 and 35,400 pounds per square inch, and the quartz porphyry (opaline granite) crushed at 38,000 pounds per square inch. The physical tests were not completed in time to be included in the discussion of each locality described.

Structural features in granites.—Common structural features in granite are joints including sheeting structure, mylonite, rift and grain, dikes, segregations, and inclusions. These features are important in determining the value of a granite. Joints may be closely spaced, widely spaced, or of intermediate spacing. Two major vertical sets, roughly at right angles to each other, are commonly present. In some deposits many directions and inclinations of joints are present, and many of them may be slickensided. Thin seams of mylonite are very common along joints in central Texas. The mylonite formed during the faulting which took place near the end of the Paleozoic, and it is quite possible that this is the date of the major joint development in central Texas. Sheeting planes (flat-lying joints) are commonly developed in granites parallel to the surface of the granite mass. The spacing of joints and sheeting is important since the size of block that can be produced is limited if they are close together, but if they are correctly spaced, the production of granite is made easier.

Most granites split easier in one direction than in any other. This direction is called the rift. A second direction of easy splitting is at right angles to the rift and is known as the grain. The third direction at right angles to both the rift and the

[16] Iddings, J. P., Igneous Rocks, John Wiley & Son, New York, vol. 1, p. 192, 1909.
[17] Holmes, Arthur, Petrographic Methods, Thomas Murby & Co., London, p. 338, 1921.
[18] Buckley, E. B., Building and ornamental stones of Wisconsin: Wisconsin Geol. Nat. Hist. Survey, Bull. 4, pp. 361, 390, 1898.

grain is known as the hard way, that is, the direction of difficult splitting.

Mr. Parkinson reports the rift to be northeast-southwest; the grain, horizontal; the hard way, northwest-southeast for the granites of the entire Central Mineral region.

Dikes both acid and basic are common in many granite areas. Basic dikes are practically absent in the granite of the Central Mineral region except for a small area along Crabapple Creek in Gillespie County. Acid dikes of aplite and pegmatite vary in their abundance and in some granites are so closely spaced that the granite cannot be used. In many of the central Texas granites acid dikes are very scarce.

Inclusions and segregations are mostly dark-colored, elongated masses within granite which spoil the appearance of stone for monumental and building stone. These are not detrimental for purely engineering works.

Granites of Central Texas

Paige[19] mapped the granites of the Llano-Burnet quadrangle and divided them into coarse-grained and fine-grained granites. The coarse-grained bodies were only in part distinguished from the fine-grained bodies; consequently fine-grained granite mapped by Paige includes some coarse-grained granite masses.

Stenzel[20] has mapped one of the granite masses of this region in detail. In connection with his mapping of this mass (the Wolf Mountain phacolith) he found that several ages of granite are present. His listing of the granites and his comments upon them follow.[21]

III. Sixmile granites; fine-grained, gray biotite granites, typically exposed in quarries near Sixmile.

II. Oatman granites; medium-grained, gray to pink, cataclastic granites, typically exposed in Oatman Creek southeast of Llano.

I. Town Mountain granites; coarse-grained to porphyritic granites, commonly with large flesh-colored feldspars, typically exposed in the abandoned quarries on Town Mountain north of Llano.

Each of these granite groups has its own dike systems of aplites and pegmatites. Lamprophyres are absent. The difference in age between some of the granite groups is considerable. Thus, in the Cassaday quarries near Sixmile there are exposures showing inclusions of Town Mountain granite in Sixmile granite. The inclusions are angular, and even the aplites that cross and belong to the Town Mountain granite are cut off sharply by the Sixmile granite. The Town Mountain granite and its aplite must have been fully solidified before intrusion of the Sixmile granite so that they could be broken into angular fragments.

The largest intrusive bodies are formed by the Town Mountain granites, as for instance the following:

a. Midway sill, exposed north of the Burnet-Llano road for 3.25 miles, located about 7 miles northwest of Burnet.

b. Lone Grove body, extending from Lone Grove to east of Bluffton (12 miles) and from the Cambrian in the north to the schist-band that strikes from Graphite to the base of Long Mountain.

c. Wolf Mountain body, exposed between Town Mountain and Wolf Mountain, 1 and 8 miles northwest of Llano respectively.

d. Granite Mountain body, exposed northwest of Marble Falls for a width of about 10 miles.

e. Enchanted Rock body, reaching from near Castell in the north to beyond the Enchanted Rock. It is about 10 miles wide and more than 14 miles long.

These bodies have much in common. The grain size of the granites is large in the centers but decreases very much to the margins and is only medium in the outlying offshoots. Color changes from red or flesh-mottled in the centers of the bodies to gray at the margins. Flow structure is noticeable everywhere; the margins especially have very strongly developed "schistose" flow structure. Contacts are chiefly concordant although cross-cutting off-shoots may be found in most exposures. Along the contacts there are many lenticular sills of granite in the country rock and long narrow inclusions of country rock in the granite. The contacts are more or less wide zones of interfingering between granite sills and country rock. Flow structure parallels the contacts and is of the plane type. Good exposures of contacts may be seen on the Llano-Burnet road at the east end of Lone Grove and east of the creek at Enchanted Rock. Nearer to the center of these intrusive bodies inclusions of country rock become less common, but they never seem to be absent. The inclusions have usually a flat, paddle-like shape and are nicely aligned with the flow structure of the igneous matrix.

The individual shape of these Town Mountain intrusive bodies is difficult to understand, and

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[19] Paige, Sidney, Description of the Llano and Burnet quadrangles: U.S. Geol. Survey Geol. Atlas, Llano-Burnet Folio (No. 183), 16 pp., 1912.

[20] Stenzel, H. B., Pre-Cambrian of Llano uplift, Texas (abst.): Bull. Geol. Soc. Amer., vol. 43, pp. 143–144, 1932; Pre-Cambrian structural conditions in the Llano region: Univ. Texas Bull. 3401, pp. 14–16, 74–79, 1934 [1935]; Pre-Cambrian unconformities in the Llano region: Univ. Texas Bull. 3501, pp. 115–116, 1935 [1936]; Structural study of a phacolith: 16th Inter. Geol. Congress, pp. 361–367, 1936.

[21] Stenzel, H. B., Pre-Cambrian structural conditions in the Llano region: Univ. Texas Bull. 3401, pp. 75–79, 1934 [1935]

it is necessary to map the entire body and to observe the contacts. The simplest body in this group is the Midway sill in Burnet County. It is about a quarter of a mile thick and exposed for a length of 3.25 miles; both ends are covered by Cambrian sediments. To the north it is bounded by gneiss; to the south by schists chiefly. Schists, gneiss, sill, and its plane flow structure strike at an average N. 70° W. and dip at an average 46° S. The gneiss underlies the granite. Obviously the gneiss-schist boundary offered an easy path for intrusion. This holds true for all Town Mountain granites that have been investigated. Their place of intrusion is the gneiss-schist boundary. Pegmatites are quite common in the Midway sill; thirty-six were encountered. Their average strike is N. 73° W. and dip is 37° N. This is very nearly at right angles to the combined average of plane flow structure and inclusions in the sill. The average strike of these is N. 64° W. and dip is 44° S. This shows that the pegmatites are intruded along a master joint set (Q-joints of H. Cloos) and that, during and after the intrusion of the sill, the greatest compressive stress was at right angles to the walls of the sill while the least stress was parallel with the walls and at right angles to the pegmatites.

Of great interest is the Wolf Mountain intrusive body. Its outcrop is roughly an inverted U that is open to the southeast. To the outside of this inverted U, in the northeast, northwest, and southwest, there is chiefly gneiss, while to the inside enclosed by the granite on three sides there are schists. These schists form the down-plunging and roughly U-shaped end of a syncline. This body is located in a synclinal trough between the gneiss and the schists. Contacts on the outside of the U, that this body outlines, dip under the granite; on the inside of the U they dip away from the granite under the schists. This body is a phacolith intruded along the gneiss-schist boundary in the trough of a syncline that plunges 16° southeast.

Flow structure in this mass is of two types, plane and linear. The plane flow structure is noticed best along the contacts and parallels the contact walls. The linear flow structure is more uniformly distributed in the phacolith. Many small spindle-shaped schist inclusions are aligned with it by their longest axes. This linear flow structure trends northwest-southeast and pitches to the southeast a little steeper than the axis of the syncline in which the phacolith lies. Pegmatite and aplite dikes are very numerous. Some of the aplite dikes attain very large proportions. Usually they cut at about right angles through the linear flow structure. Therefore, the majority of the dikes strike northeast-southwest and dip to the northwest in this body. Flow structure and dikes in the phacolith indicate that the greatest compressive stress was in northeast-southwest (or opposite) direction; least stress was in the direction of linear flow structure. As a whole, indicated stress conditions in the granite were identical with the stress conditions indicated by the open folds of the gneiss and schists in which the granite intruded. This apparently means that the granite was intruded under tectonic pressures similar to the pressures that produced the folds in the folded frame, or, in other words, the phacolith was intruded at the end of the period of folding of the frame.

An interesting problem presents itself in the question of location of the feeding channel for the phacolith. Did the granite magma rise along the pitching keel of the syncline or did it rise along other channels? The phacolith is not very symmetrical. Of the two branches of the U the northeast branch is over three times as wide as the southwest branch. If the size has anything to do with proximity to feeding channels, the channel should be in the northeast. Along the outer northeast contact of the phacolith there is a zone of crumpled gneisses and schists. The zone is exposed in many places from Pecan Creek west-northwest of Horse Mountain to a left tributary of Mitchell Creek southwest of Miller Mountain for a length of 5.5 miles at least. It is about 100 to 500 feet from the granite contact. In this zone the crumpled schists or gneiss are welded together by tortuous granite stringers but pegmatites cut straight through stringers and all. The crumpling, therefore, was older than or contemporaneous with the granite intrusion. The crumpling in this narrow shear zone was produced by a shear of northwest-southeast trend in which the northeast block moved to the southeast. In the continuation of the shear zone to the northwest, the phacolith has its greatest length and ends in two long narrow tips that are accompanied by several larger sills of the same granite. These sills contain large grained granite, while sills in the south end of the phacolith west of Llano have much finer grain. All these features make it very probable that the feeding channel of this body is near this shear zone along the northeast contact.

The Oatman granites form elongate outcrops southeast and northwest of Llano. The arrangement is *en échelon*. The details of the contacts of these bodies are very irregular, the granites erratically cross-cutting at the contacts. Yet the general alignment of the bodies is with the strike of the schists. Near Llano the trend of the bodies is northwest-southeast, but in the vicinity of Sharp Mountain the schists and with them the granites make a right angle turn and strike northeast-southwest and dip to the southeast. The fiber of the schists continues in the old direction, northwest-southeast trend with southeast pitch. I believe the Oatman granites to be intruded along strike faults or strike fractures. These are possibly produced by a shear motion not unlike the *en échelon* faults of Oklahoma according to A. E. Fath.[22] If this be the case, the shear would be corresponding to the shear in the crumpled zone of the Wolf Mountain phacolith, the northeast block moving relatively to the southeast.

The Sixmile granites were not investigated in detail because exposures of contacts did not seem to be abundant.

The last igneous activity in the region is represented by the opaline quartz-porphyry and its allies. These late dike intrusions have a flow structure that is parallel to the walls. The walls

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[22]Fath, A. E., The origin of the faults, anticlines, and buried "Granite Ridge" of the northern part of the Mid-Continent oil and gas field: U. S. Geol. Surv. Prof. Paper 128-C, pp. 75-84, 1920.

were rigid during their intrusion. The dikes lie in a prominent fracture system of north-south direction that seems to foreshadow some of the later Paleozoic north-south faults.

Keppel[23] made a structural examination of the granites of the Lone Grove (Buchanan) and Granite Mountain (Kingsland and Marble Falls) "massifs" and hastily examined some of the other granite bodies of the area. The summary and conclusions of Keppel are quoted below:

(1) The massifs are steep-walled, roughly circular bodies, 10 to 12 miles in diameter, flanked by schist and gneiss.

(2) Within the massifs there are concentric bands of different textural varieties of granite—coarse-grained granite on the outside, porphyritic coarse-grained granite in the intermediate ring, and medium-grained granite (often containing occasional phenocrysts) in the core.

(3) Contacts between the rocks of different texture are usually gradational.

(4) The concentric bands are cut by small bodies of fine-grained granite in the center of the massifs, around the margins, and in radial dikes and elongated masses.

(5) The sequence of solidification for the textural varieties is shown to be as follows: coarse-grained granite, porphyritic coarse-grained granite, medium-grained granite, and fine-grained granite.

(6) Comparison of the type massif of the area with other granite occurrences reveals a repetition of the same general features, although there are exceptions. The most common textural type for the region as a whole is porphyritic coarse-grained granite.

(7) It is believed that the massifs were intruded vertically into the crust and that differentiation into textural phases accompanied the intrusion. Suggestions are offered to explain the porphyritic texture and the finer grain size of the central core as compared with the margins.

Goldich[24] made a chemical and petrographic examination of several granites of the area including the Lone Grove and Granite Mountain bodies examined by Keppel. An abstract of Goldich's paper is quoted as follows:

This paper presents chemical and petrographic data for certain granitic rocks in the Llano uplift region of central Texas. The samples include five granites, a granite-porphyry dike rock, and an aplite. The chemical and petrographic characters of these rocks suggest close relationship, and the variation of the oxides with silica content (68–77 per cent) is shown in the usual variation diagram. It is possible that the granites were evolved by the fractionation of one or more related or chemically analogous liquids. The mechanism favored to explain the origin of the granites is a process similar to "filter-pressing" acting in late stages of the fractional crystallization of the magma. The escape of the hyperfusibles which are concentrated in the residual alkalic liquids in the late stages of crystallization may have been effective in initiating the filter-pressing mechanism. This process is considered to be competent to explain the chemical and textural characteristics of the central Texas granites.

Sandell and Goldich[24a] have made a study of some of the rarer metallic constituents of the same rocks as described in the paper mentioned above.

Much granite remains to be mapped in Mason County, and much remains to be learned about the granites of the rest of the area. The groupings made by Stenzel may be somewhat changed, and other groups may be added as detailed mapping progresses.

For convenience to the reader the granites have been separated into two groups. The first group discussed is the granites which are gray or predominantly gray. The second group discussed is the granites which are predominantly pink and red. A few granites are of a color which makes it difficult to include them with either group. They have, however, been placed with the group of nearest affinity.

GRAY GRANITES

Resumé.—Commercially important gray granites are present in at least five counties of central Texas. The most accessible deposits are in Llano County, and others are present in Mason, Burnet, Gillespie, and Blanco counties. As in all granite areas, various grades of granite are present. The majority of the gray granite is of superior quality and only a small amount of inferior quality. Several deposits contain enormous amounts of stone as good as, and in some cases excelling, that found elsewhere in the United States. Certain unfair trade practices, consisting mainly in the misrepresentation of Texas granites, have been used to discourage the development of a local industry. It is hoped that the facts set down in the following pages will be sufficient to eliminate such questionable practices.

[23]Keppel, David, Concentric patterns in the granites of the Llano-Burnet region, Texas: Bull. Geol. Soc. Amer., vol. 51, pp. 971–1000, 1940.

[24]Goldich, S. S., Evolution of the central Texas granites: Jour. Geol., vol. 49, pp. 697–720, 1941.

[24a]Sandell, E. B., and Goldich, S. S., The rarer metallic constituents of some American igneous rocks: Jour. Geol., vol. 51, pp. 99–115, 167–189, 1943.

A system of locality numbers has been used in numbering all specimens. Index letters for the counties are used, and each specimen as collected is given a number. For example, Sample Bl–20 is the twentieth specimen of building stone collected in Blanco County. Since these numbers have become so intimately associated with the localities and the specimens from these localities, they will be used in this paper.

The gray granites are composed predominantly of microcline, plagioclase, quartz, and biotite. Four of the darker colored ones contain hornblende. The lightest colored granite contained a small amount of muscovite, and a small amount of muscovite is present in the granite of the Kansas City quarry. Of the accessory minerals, apatite is present in all of the granites except Bl–1, magnetite is present in all except two granites, and titanite and zircon are present in about half of the granites. Rutile is commonly present, and ilmenite was detected in three of the granites which also contained reticulated quartz. Fluorite is present in one granite from Blanco County. The minerals chlorite and sericite formed by alteration are almost invariably present. Other alteration minerals found are albite in one granite, calcite in one granite, and epidote in two granites. Pyrite is present in six of the granites and is very objectionable in three of them. The pyrite in the other three is apparently stable and does not break down upon continued exposure to the weather. In Table 1 the mineral composition of the granites is given. The actual estimated percentage is given for the more common minerals, and the presence of other minerals is indicated by an x. The table undoubtedly is incomplete as it is practically impossible to detect all the minerals, especially since the volume of granite contained in a thin section is exceedingly small. Zircon, for instance, is probably present in every granite but was not found in 25 per cent of them because of an insufficient amount of granite in thin section. The plagioclase feldspar is mostly oligoclase in composition. The composition of the plagioclase was determined from the optical properties of crystals oriented by the aid of a universal stage. The plagioclase has a small range in composition in each granite, and an average value for this range is given.

Table 1. Mineral composition and grain size of central Texas gray granites.

Sample	Microcline	Plagioclase	Quartz	Biotite	Hornblende	Muscovite	Magnetite	Titanite	Apatite	Fluorite	Zircon	Rutile	Ilmenite	Sericite	Chlorite	Albite	Calcite	Epidote	Pyrite	Reticulated quartz	Grain size in mm.
Bl–6	25	44	28	2		1				x	x			x	x						1
Bl–20	17	43	20	8	4		x	x	x		x				8	x		x			3
Bu–17	12	60	15	9	1		1	2	x		x	x	x	x	x		x	x	x	x	2*
G–12	4	57	29	9	1		x	x	x		x			x	x				x		2.5
Ll–17	35	26	33	5			x		x					1	x						1
Ll–21	30	33	33	4			x		x			x		x	x						0.5
Ll–22	24	38	33	5			x	x	x			x		x	x						1
Ll–24	35	30	31	4			x		x		x			x	x				x		2
Ll–25	38	36	22	4			x		x		x			x	x						2
Ll–26	27	45	22	6			x	x	x		x			x	x				x		1.5
Ll–37g	26	38	30	6			x	x	x		x			x	x						2
Ll–37p	29	35	29	6	x		x	1	x		x	x			x				x		2.5†
Ll–39	31	31	34	4			x	x	x					x	x						1
Ll–40	26	43	26	5			x		x		x			x	x						1.5
Ll–52	33	32	31	3			x	x	x		x			x	x						2
Ll–65	33±	33±	30	3			x		x			x	x	x	x					x	1.5
Ll–66	47	21	28	4					x		x	x	x	x	x				x	x	3
Ll–67	37	14	46	3		x	x		x		x			x	x				x		4
M–6	35	29	31	5			x		x		x			x	x						1
M–23	33	32	30	5			x		x		x			x	x						1

*This is a porphyritic granite in which the phenocrysts average about 10 mm. in length.

†This is a porphyritic pinkish-gray granite produced from the same quarry as the fine-grained gray granite Ll–37g. The phenocrysts average about 15 mm. in length.

The gray granites all contain more or less zoned plagioclase in which the central portion of the crystal is more basic than the outer portions. Insufficient crystals were measured to give the range in composition, but the average value given is probably a close approximation.

Table 2 which follows states the name either of the quarry or of the property from which the granites were obtained, the distance of the deposit to a railroad, and an estimate of the grain size of the granites. The grain size ranges between about 0.5 mm. and about 3 mm., with two porphyritic granites, G–12 and Ll–37p, in which the phenocrysts average about 10 and 15 mm. in length respectively.

Physical tests for the central Texas gray granites are given in a separate chapter. They were not available for inclusion in the discussion of each locality described.

Table 2. Location by quarry or property name and distance to railroad of central Texas gray granites.

County	Sample No.	Name of owner or operator of quarry or property	Distance to railroad in miles
Blanco	6	Scharnhorst property	27
Blanco	20	Hardin property	31*
Burnet	17	Shannon quarry	7.7
Gillespie	12	Unknown	20
Llano	17	Unknown	15
Llano	21	Cone property	7.5
Llano	22	Hill quarry	8.5
Llano	24	Norton quarry	16.5
Llano	25	Charles Moss property	13.5
Llano	26	Hilltop quarry	12
Llano	37g	Parkinson group	6.5
Llano	37p	Baldwin quarry	6.5
Llano	39	Premier quarry (Slater property)	7.5
Llano	40	Premier quarry (Stewart property)	12
Llano	52	Hamilton property	5
Llano	65	Curley quarry	7
Llano	66	Stribling property	4.5
Llano	67	Kansas City quarry	2
Mason	6	Blodgett quarry	26.5
Mason	23	King Mountain quarry	25.7

*This distance is to Fredericksburg which is no longer on a railroad.

The gray granites were arranged by visual examination into a series ranging from coarse grained to fine grained. This arrangement is shown in Table 3, with the estimated grain size determined microscopically given for comparison. Two of these granites have been inserted in this series from microscopic measurements only, namely, Ll–21 and M–23.

Table 3. Grain size of central Texas gray granites.

	Average grain size in mm.	Average length of phenocrysts in mm.	
Ll–37p	2.5	15	(coarsest)
G–12	2.5*	10	
Bl–20	3		
Bu–17	2		
Ll–25	2		
Ll–37g	2		
Ll–52	2		
Ll–24	2		
Ll–40	1.5		
Ll–26	1.5		
Ll–39	1		
Ll–22	1		
Bl–6	1		
Ll–17	1		
M–6	1		
M–23	1		
Ll–21	0.5		(finest)

*Average grain size of mesostasis.

The off-color granite from the Curley quarry (Ll–65) has a grain size of about 1.5 mm., and the pyritic granites of the Stribling (Ll–66) and Kansas City (Ll–67) quarries have a grain size of about 3 and 4 mm. respectively.

To describe the color of a rock adequately is almost impossible. In order to give a little more definite information about the color, the polished specimens were arranged in a series ranging from light to dark. Table 4 gives the position of each polished specimen in this series, except Ll–17 and M–23, for which polished specimens are not available, and Ll–52, Ll–37, and G–12, which contain pink in addition to gray.

Table 4. Central Texas gray granites arranged in order of increasing intensity of color.

Bl–6	(light colored)
Ll–21	
Ll–39	
Ll–22	
Ll–24	
M–6	
Ll–25	
Ll–40	
Ll–37g	
Ll–26	
Bl–20	
Bu–17	(dark colored)

Under Ll–37g the rock from the Baldwin quarry is noticeably darker than that from the Cassaday and Norton quarries. However, both these specimens fell between Ll–40 and Ll–26. Ll–52 was not placed in the above series because of its pink color. It appears, however, that fresh unaltered rock from this locality might fall near Ll–37. The granites from Gillespie County (G–12) and the porphyritic granite from the Baldwin quarry (Ll–37p) have phenocrysts of pink feldspar in them and cannot properly be placed in this color variation list. The areas between the phenocrysts are in color nearer the dark end of the series.

The granites from M–6, M–23, Ll–21, Ll–22, Ll–25, Ll–26, Ll–37, Ll–39, and Ll–40 are exceptionally good. The granite from Ll–24 contains some pyrite which may be objectionable; otherwise it is a very good stone. The dark granites from Bl–20, Bu–17, and G–12 are of fair quality. The granite from the Curley quarry (Ll–65) is not uniform in color. The granite from Ll–52 is of a pinkish-gray color and may be non-uniform in color. The granites from the Kansas City (Ll–67) and the Stribling (Ll–66) quarries contain pyrite which decomposes, causing unsightly stains. These two granites are valueless as building stones.

The locations of all the granites discussed in the following section are shown on Plate 1 (folded in pocket).

Description by Localities

Blanco County

LOCALITY BL–6

Location and geology.—A granite mass is located about 5 miles southwest of Sandy post office and about 27 miles by road from the nearest railroad, which is at Marble Falls. Thirteen miles of the road is hard surfaced, and the rest is mostly unimproved.

The granite is of a different type than is found elsewhere in Blanco County. It varies in color from almost white to pink and red and varies widely in texture from fine to medium grained. Pegmatites, aplites, and inclusions are numerous. The granite weathers into fantastic shapes because of its non-uniformity in composition and the abundance of inclusions and dikes. About a half square mile of outcropping granite was seen. It is almost without value except for the small masses of fine-grained, almost white granite that are present. To the east and south, Cambrian sandstone overlaps the granite.

Megascopic description.—The granite is almost white except for a pinkish cast from microcline and a grayish cast from biotite. The biotite is not uniformly distributed; thus a faintly mottled appearance is given to the granite. Some biotite flakes and quartz crystals up to 3 mm. across are present and are irregularly distributed. The granite takes a poor polish and in reflected light has a pitted or sand-blasted appearance due to difference in relief of the very small mineral grains, which average less than 1 mm. in size.

Microscopic distribution.—The granite is composed predominantly of plagioclase, microcline, and quartz. Only a minor amount of biotite and muscovite is present. Accessory minerals are very scarce and consist of zircon and fluorite. Alteration products are chlorite and sericite which are extremely scarce. The feldspars are mostly clear with only an occasional one being flecked by cloudy areas. The plagioclase is oligoclase in composition. The estimated mineral composition[25] is plagioclase 44, quartz 28, microcline 25, biotite 2, and muscovite 1 per cent. The granite is a soda-potash granite. The quartz is mostly without undulatory extinction. Some of the microcline crystals form a mesh about small, rounded quartz grains, producing a sieve-like texture. The average grain size is less than 1 mm.

Recommendations.—The granite is an excellent stone for use as a base course in buildings made of light-colored limestones and marbles. The color is such that it would blend well with the stone of the building, yet would not permanently stain from contact with the soil. From the field examination, it is judged that the light-colored granite is rather scarce and that it may not be present in quantities sufficient to quarry. It may also be non-uniform in color.

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[25] All estimations of mineral composition throughout this paper, unless otherwise indicated, are by the Rosiwal method, which is a method of estimating mineral composition by traversing a thin section under the microscope, counting the intercepts of each mineral on a scale divided into 100 parts. Several traverses are necessary to obtain an accurate estimate.

LOCALITY BL–20

Location and geology.—A granite mass is located in the northwestern corner of Blanco County, 0.2 mile east of the Hardin cemetery on the Davis ranch. The granite mass is about 31 miles by road from Fredericksburg. The first 1.3 miles of the road is little better than a trail; the next 17.7 miles is mostly graded but otherwise unimproved; and the last 12 miles is hard surfaced. The granite is located about 24 miles from Marble Falls by road which is mostly graded.

The granite outcrop is low lying and does not stand more than 5 feet above the surrounding, rather flat area. One massive outcrop is about 50 by 150 feet in area, and others are scattered about in the vicinity. A few black inclusions and some light-colored pegmatites are present. The most prominent joint directions trend north-south and east-west. Flow structure trending N. 65° E. and dipping steeply southward is well developed.

Megascopic description.—The granite is medium grained with biotite areas up to 1 cm. in diameter. The biotite areas are uniformly distributed and show some tendency toward alignment. The granite is very dark gray and is next to the darkest of the granites examined from central Texas. A photograph of a polished surface is shown in Plate 4.

Microscopic description.—The granite is composed predominantly of plagioclase, microcline, quartz, biotite, and hornblende. Accessory minerals are rather abundant and consist of titanite, magnetite, apatite, and zircon. A few pleochroic halos are present in the biotite. Minerals formed by alteration are chlorite, epidote, and albite. The albite was produced by alteration, chiefly from the more basic plagioclase. The granite is much altered and appears to have been originally composed essentially of plagioclase, microcline, quartz, biotite, and hornblende having an average grain size of about 3 mm. All of these minerals, except possibly the quartz, have been in part altered and replaced. The biotite is about half altered to chlorite, with some epidote being present. The biotite, chlorite, and hornblende have in part a sieve-like structure and contain a colorless mineral, which is probably either albite or quartz, widely distributed in them. Shear zones cut the microcline crystals, and in these zones the microcline is replaced by a very fine-grained mixture of plagioclase, quartz, and biotite. The replacement of many of the plagioclase feldspars is still more complete with only remnants of the original crystal remaining in a granular mass of albite, quartz, and biotite. Some of the quartz appears to have been under sufficient stress to cause it to shear. The chloritization and albitization may have taken place closely following the shearing. No particularly deleterious minerals were seen. The plagioclase is mostly andesine with some that is oligoclase in composition.

The estimated mineral composition is plagioclase 43, microcline 17, quartz 20, biotite 8, hornblende 4, and chlorite 8 per cent. These percentages are only approximate since much alteration has taken place, producing areas of intimately intermixed minerals in which it was impossible to differentiate closely the various minerals.

From the mineralogic composition this rock would be classified as a granodiorite. An examination of powdered samples of several other gray, gneissic rocks south of this area reveals that they are predominantly composed of oligoclase-andesine feldspar, quartz, biotite, and hornblende. These rocks are, therefore, quartz diorites.

The strength of this rock will be somewhat below that of most central Texas gray granites because of the large amount of biotite and chlorite. Alteration and replacement changed the original structure of the rock, but apparently not in sufficient amount to cause it to be hard to work. The chlorite will take a dull finish upon polishing.

Chemical analysis.—The granite was not analyzed, but a similar rock from Gillespie County, 4 miles to the south-southwest, somewhat more dioritic and gneissic in character, was analyzed. The analysis is given in Table 5 which also includes the normative mineral composition as calculated from the analysis.

Table 5. Gillespie County granodiorite.

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	64.37	Quartz	18.54
Al_2O_3	18.14	Orthoclase	6.12
Fe_2O_3	1.05	Albite	38.25
FeO	2.49	Anorthite	25.85
MgO	1.90	Diopside	0.89
CaO	5.65	Hypersthene	7.30
Na_2O	4.54	Magnetite	1.62
K_2O	1.00	Ilmenite	0.76
H_2O+	0.40	Apatite	0.31
H_2O-	0.02	Fluorite	0.07
CO_2	0.02	Calcite	0.05
TiO_2	0.44	Pyrite	0.04
P_2O_5	0.13		
MnO	0.04	Normative plagioclase $Ab_{60}An_{40}$	
BaO	0.04	Symbol I(II).4.3.4(5).	
F	0.03		
S	0.02		
	100.28		
Less O	0.02		
	100.26		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysts: R. B Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

A comparison of the normative mineral composition obtained from the analysis with the modal mineral composition of BI–20 indicates that the rocks are not strictly comparable. The analysed rock is higher in plagioclase feldspar and is lower in orthoclase feldspar and femic minerals. The deleterious minerals calcite and pyrite are present in very minor quantities.

Recommendations.—The granite is the second-darkest gray granite examined in central Texas and may be of some utility where a particularly dark gray rock is needed. The chief disadvantage to its use is the great distance that it must be transported to a railroad. It takes a sufficiently good polish and is strong enough to be used as a building stone.

Burnet County

LOCALITY BU–17 (SHANNON QUARRY)

Location and geology.—The Shannon quarry is located 7.7 miles by road west of Burnet. The road from the quarry to the old Llano-Burnet highway, 2.7 miles, is unimproved and scarcely passable. The old highway is an all-weather road, and the rest of the highway into Burnet, 3.5 miles, is hard surfaced. A map which includes this granite area is shown in figure 2.

Three small openings have been made in the granite mass. The southeastern one, which is near the top of the mass, exposes many inclusions of Valley Spring gneiss in the granite. The other two quarries are near the bottom of the mass, and the granite is almost free of inclusions. The granite is in the form of a sheet which dips 5°, S. 20° E. Two sets of joints trend N. 40° W. and N. 35° E. Sheeting joints are about parallel to the upper surface of the granite.

Megascopic description.—The granite is of somewhat uneven texture, is medium grained, and has a definite mineral alignment. Areas of light-colored minerals up to three-fourths of an inch long are irregularly distributed in a rather uniform, very dark groundmass. This is the darkest gray granite examined. It takes a beautiful polish, but carving is barely visible upon it because of a lack of contrast between polished and rough surfaces.

Microscopic description.—The granite is composed predominantly of plagioclase, quartz, microcline, biotite, and hornblende. Accessory minerals are abundant and consist of titanite, magnetite, apatite, and some zircon. A few pleochroic halos are present in the biotite. Reticulated quartz is present containing long needles of rutile and plates of ilmenite.

Minerals formed by alteration are calcite, epidote, chlorite, and a very small amount of sericite. The biotite has altered in part to a chlorite having an abnormal lavender interference color. Sericite formed from the feldspars is very scarce. The feldspars show some clouding mostly as irregularly distributed flecks. The plagioclase is mostly oligoclase in composition with an occasional basic center or individual being andesine. Two large zonal crystals measured have a composition of Ab_{66} at the center and Ab_{73} at the border. Albite-twinned feldspars without zoning have compositions averaging about Ab_{74}. The estimated mineral composition is plagioclase 60, quartz 15, microcline 12, biotite 9, titanite 2, hornblende 1, and magnetite 1 per cent. A few small crystals of pyrite are present. On the basis of its

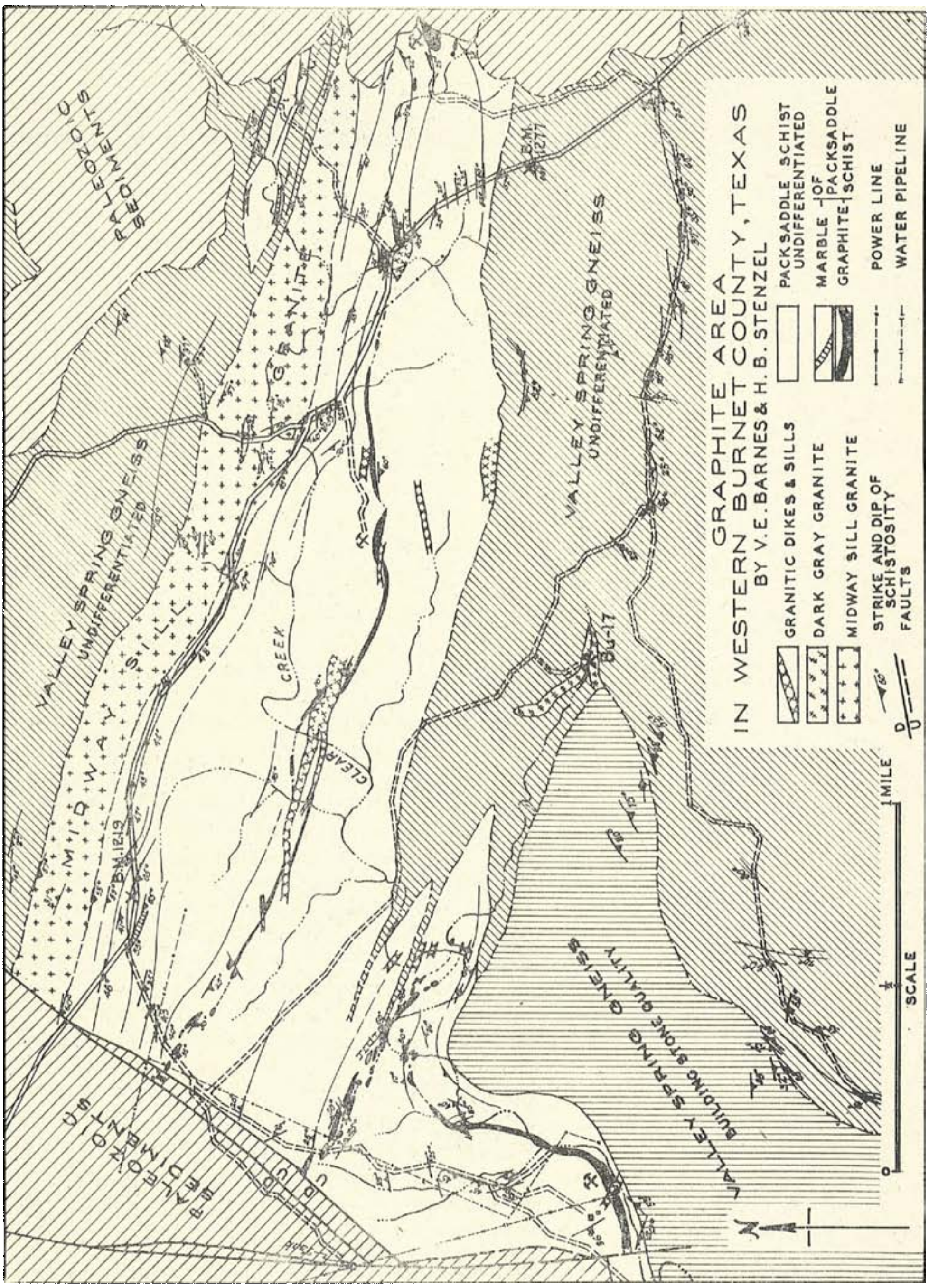

Fig. 2. Geologic map of the graphite area in western Burnet County, Texas.

mineral composition the rock may be classified as a biotite-hornblende granite or a granodiorite.

The average grain size of the coarser crystals is about 2 mm. with some crystals almost 4 mm. across. Between the larger crystals there are many ranging near 0.5 mm. across. Micropegmatite is common. The quartz is practically without undulatory extinction.

Recommendations.—The granite is the darkest of the gray granites examined in central Texas and may be of value where a dark rock is needed. It has one disadvantage in that there is little contrast between designs carved upon a polished surface and the polished surface itself; consequently, it is not desirable for monumental work where such contrast is needed. The mineralogical composition of the granite and the interlocking character of the grains are such that it is strong. The presence of pyrite is objectionable and might cause staining if the rock were exposed in certain climates. The blocks quarried and left lying about for many years, however, are not stained. This granite is a very good building stone.

Gillespie County

LOCALITY G-12 (BELL MOUNTAIN)

Location and geology.—A granite mass was sampled in a cut along the old Llano-Fredericksburg highway 3 miles south of the Llano-Gillespie County line, about 18 miles from Fredericksburg and 20 miles from Llano. The new highway is hard surfaced from the outcrop to both towns.

The area is now mapped, but work was not completed in time to use the data in this publication. The coarse-grained gray granite which was sampled is a contaminated pink granite. The boundary of the coarse-grained pink granite mass is extremely irregular, and many tongues of it penetrated into the schists and gneisses of the area. The schists and gneisses were in part assimilated and in part granitized. The dark-colored hornblende and biotite schist when assimilated darkened the granite; the light-colored schists and quartzites when assimilated had little effect on the color of the granite. The color of the granite tongues, therefore, varies widely, ranging from pink in some, to dark gray in others, to gradational from pink to gray in still others. All dark-colored tongues of the granite which can be traced directly to the main granite mass have, however, a gradational change in color to the pink of the main mass. The granitization of the intruded schists is well shown in this area. The darker colored schists when granitized produce a gray gneiss, the lighter colored ones a pink gneiss, and some of the intermediate ones were formed into a pinkish-gray gneiss. Much of the schist has been granitized, but sufficient unaltered schist is present so that the changes which took place can be easily recognized.

Some of the dark-colored granite tongues are of uniform-colored stone relatively free of inclusions, aplites, and pegmatites. Many, however, are not uniform in color, contain numerous inclusions, and are much cut by aplites and some pegmatites. The granite at the original locality sampled contains pyrite. Some granite of the area, however, is free from pyrite. Joints are rather numerous. The granite outcrop is rough and boulder strewn.

Megascopic description.—The granite is coarse grained and predominantly dark gray. Scattered through it are small phenocrysts of pink feldspar averaging less than half an inch in length. These phenocrysts give the rock a slightly pinkish cast. Less than 10 per cent of the rock is composed of pink feldspar. The rest of the rock is composed of quartz, biotite, and cloudy to clear feldspar. Some pyrite and magnetite are present. The granite has a gneissic texture and the minerals are well aligned. This granite is transitional in color and is placed here since it is more dominantly gray than pink.

Microscopic description.—The granite is composed predominantly of plagioclase quartz, microcline, and biotite. Hornblende is present in minor amounts. Accessory minerals are titanite, magnetite, apatite, and zircon. A small amount of pyrite is present, and a few pleochroic halos were seen in the biotite.

Minerals formed by alteration are chlorite from biotite and a small amount of sericite from the more basic feldspars. The feldspars are mostly only flecked by cloudiness with a few of the more basic ones being almost entirely cloudy. Some granulation and alteration have taken place in narrow zones mostly along grain boundaries. In a few places these zones cut across and displace feldspar crystals. The minerals in these granulation zones are too finely granular to identify with certainty, but some material of low refractive index is present which may be albite.

The plagioclase is mostly andesine in composition and contains an average of about 68 per cent of the albite molecule. Zoned crystals are not abundant, and the range of composition is rather small. The estimated mineral composition is plagioclase 57, quartz 29, microcline 4, biotite 9, and hornblende 1 per cent. The granite is a quartz-mica-diorite produced by the assimilation of schist.

The average grain size of the granite is about 2.5 mm., with some feldspars attaining a length of 10 mm. The quartz is in elongated areas, and each area is a mosaic made up of numerous quartz particles. It is possible that each of these areas was originally one quartz grain and that this is an advanced stage of the incipient shearing observed in the quartz of most of the gray granites. In this quartz, however, the grain boundaries are mostly definite breaks, whereas in the incipiently sheared quartz of other gray granites the fragments are not separated by breaks.

Chemical analysis.—A chemical analysis of a similar granite sampled along the new highway and the normative mineral composition as calculated from the analysis are given in Table 6.

Table 6. Bell Mountain granite

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	63.09	Quartz	14.82
Al_2O_3	17.37	Orthoclase	17.24
Fe_2O_3	1.33	Albite	36.15
FeO	3.33	Anorthite	16.68
MgO	2.14	Corundum	1.12
CaO	3.75	Hypersthene	9.39
Na_2O	4.30	Magnetite	1.86
K_2O	2.93	Ilmenite	1.22
H_2O+	0.52	Apatite	0.59
H_2O-	0.06	Fluorite	0.16
CO_2	0.06	Calcite	0.14
TiO_2	0.65	Pyrite	0.06
P_2O_6	0.25		
MnO	0.12	Normative plagioclase $Ab_{68}An_{32}$	
BaO	0.15	Symbol I(II).4″.(2)3.4.	
F	0.10		
S	0.03		
	100.18		
Less O	0.05		
	100.13		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysts: R. B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

The calculated mineral composition of the sample collected along the new highway does not compare very closely to the measured mineral composition of the sample collected along the old highway. The amount of plagioclase, however, is about the same. The calculated orthoclase is high since it is based on all of the potash, whereas much of this potash is in the mineral biotite. The calculated quartz is only half that of the measured quartz. Such a wide difference must be mostly accounted for by an actual chemical and mineralogical difference between the two rocks.

Chemically the granite from which the analysis was obtained is a good granite. The content of the deleterious minerals calcite and pyrite is very low.

Recommendations.—The granite is rather widespread and may be found in masses sufficiently free of inclusions to be of use for a building stone. It is not as desirable as many of the other granites of central Texas, but it is of good color and is of sufficient strength for any purpose for which is might be used. The principal objection to the use of this granite is the nonuniform color and composition. Some areas contain pyrite which might or might not be objectionable. Much care would have to be taken in selecting a quarry site in this area in order to obtain a sufficient amount of uniformly colored stone, free of inclusions and other imperfections.

Llano County

LOCALITY LL–17

Location and geology.—A fine-grained gray granite mass is located by road 15 miles northwest of Llano and 3 miles northeast of Valley Spring. It is 15 miles from the railroad at Llano. Two roads lead to Llano on which the distances are the same. The one by Valley Spring is graded but not hard surfaced. The one to the eastward is graded to the paved San Saba-Llano highway 3.5 miles north of Llano.

The granite mass, situated along a small drain, is low lying and poorly exposed, being located at the edge of the overlying Cambrian Hickory sandstone. The basal Hickory conglomerate is exposed lying on granite along the drain to the west of the quarry. The first foot of the conglomerate is an angular quartz rubble above which rounded and wind-faceted pebbles are found.

A small quarry was opened in the granite, and after some monumental stone had been removed the quarry was abandoned. The granite is very fine grained, even textured, and of a gray color. A few black inclusions, mostly less than an inch across, were seen in the quarry waste. Two sets of joints trending N. 70° E. and N. 25° W. are rather closely spaced, being very seldom as much as 6 feet apart. One pegmatite vein about one-fourth of an inch thick trends across the outcrop in a direction N. 60° E. One quartz vein of the gash vein or tensional type trends N. 40° W. Sheet joints are present which dip gently to the south.

Megascopic description.—The granite was not polished. The rough stone is of a light gray, pleasing color.

Microscopic description.—The granite is composed predominantly of microcline, quartz, plagioclase, and biotite. Accessory minerals are rather scarce and consist of magnetite and apatite. Minerals formed by alteration are chlorite and sericite.

The biotite has in part altered to chlorite, going through a stage in which the mineral is green with high birefringence. The final product, chlorite, is green with low birefringence. The feldspars are somewhat incipiently altered; in some places they have changed to sericite, and in others they are cloudy. The central, more basic part of the oligoclase is mostly cloudy while the outer portion is entirely unaltered. The microcline is not uniformly cloudy but may be entirely clear or flecked by cloudy areas. This granite contains more sericite than any other gray granite examined. Much of the alteration is caused by near-surface conditions and with depth will disappear.

The plagioclase is oligoclase in composition, containing an average of about 80 per cent of the albite molecule. The estimated mineral composition is microcline 35, quartz 33, plagioclase 26, biotite 5, and sericite 1 per cent. No deleterious minerals were found. This granite is a soda-potash granite, and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

The average grain size of the granite is about 1 mm. with occasional grains over 2 mm. in size. The grains are well interlocked. A small amount of micropegmatite is present. The quartz crystals have both undulatory extinction and a mosaic appearance when near extinction. The mineralogical composition of the granite and the size and interlocking arrangement of the grains are such that this granite is strong and will be durable.

Recommendations.—The granite appears very fresh and is a desirable stone. The joints are rather numerous, which would cause much waste and limit the size of blocks which could be produced. The rock has been exposed to two cycles of weathering, which has deteriorated some of the minerals, and it would be necessary to discard much of the near-surface rock. The deposit is low lying, and any quarry opened would be subject to overflow. Many other much more favorably located deposits are known; consequently, this one is mentioned for future reference rather than for present utility.

LOCALITY LL–21

Location and geology.—A small amount of gray granite has been removed from the lower eastern flank of the next hill south of Hickory Mountain. A large mass of granite is located here, which is about 1 mile west of the paved Fredericksburg-Llano highway, at a point 6.5 miles south of the railroad in Llano.

The surface few feet of granite is pinkish gray from weathering, and at a few feet in depth the rock is light gray. No inclusions were seen, and pegmatites are rare. Another old quarry in good granite is located about 0.3 mile due west on the western flank of the same hill.

A quarry has been opened in a pyritic granite about 1 mile north of these two good quarries and about one-fourth of a mile north of Bachelor Peak. The pyritic granite is of no value and is not to be confused with the exceptionally good granite south of Hickory Mountain.

Megascopic description.—A few biotite flakes up to about 1 mm. in size are widely scattered in the granite. Pin point-sized biotites are rather uniformly distributed. A few small areas not containing biotite are present, causing a faintly mottled appearance in the granite. The granite is the second-lightest colored one examined, and it has a slightly pinkish cast. It is an extremely fine-grained granite and polishes to a very smooth surface.

Microscopic description.—The granite is composed predominantly of microcline, quartz, and plagioclase, with a small amount of biotite. Accessory minerals are very scarce and consist mostly of magnetite, apatite, and rutile. The rutile is scarce and is present as long needles in quartz. Minerals formed by alteration are also scarce, only a small amount of chlorite and sericite being present. The granite is almost free of alteration. A very small amount of chlorite formed from biotite and an insignificant amount of sericite formed from feldspar are present. The feldspars are in part slightly cloudy, with the oligoclase being cloudy at the center and clear at the borders and the microcline being flecked by cloudy areas.

The plagioclase is oligoclase in composition and is present as phenocrysts somewhat larger in size than the grains of other minerals. The oligoclase varies in composition and contains an average of about 82 per cent of the albite molecule. In some of the zoned oligoclase crystals the center is 78 per cent albite and the border is 85 per cent albite. The estimated mineral composition is microcline 30, quartz 33, plagioclase 33, and biotite 4 per cent. No deleterious minerals were seen. This granite is a soda-potash granite and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

The average grain size is about 0.5 mm. with very little variation either way. A few crystals of plagioclase are as large as 2.5 by 1 mm. in size. The grains are equidimensional and interlocking. The quartz has very little undulatory extinction.

Recommendations.—The light gray granite south of Hickory Mountain is an exceptionally good stone. It is next to the lightest-colored gray granite examined in central Texas and is an excellent monumental and building stone. It is the strongest gray granite examined, which makes it of value where great strength is needed.

LOCALITY LL-22 (HILL QUARRY)

Location and geology.—A large mass of gray granite is located about 7 miles west of Llano and 1 mile south of the Llano-Mason highway. It is 8.5 miles from the nearest railroad, which is at Llano. The road from the quarry to the highway is unimproved, and the highway is graded but not hard surfaced.

The granite is in a flat, gently-sloping area and is not well exposed except in the quarry. The overburden, however, is thin, and very little material must be stripped to expose the granite. The quarry is about 250 feet long and of irregular width. Ten feet of granite is exposed to water level, and the depth to which the quarry extends below water level was not determined.

The main joints trend N. 65° E. and N. 40° W. Two narrow pegmatite veins about 4 inches thick trend north-south and dip at a low angle to the east. Discolored or "sap" zones parallel the pegmatites as well as most of the joints. The joints are rather widely spaced; consequently, little stone will be lost because of sap. There are a few light-colored inclusions in the granite. The quarry has not been operated for several years, but much of the quarrying equipment is still present.

Megascopic description.—The granite is fine grained and of uniform texture. An occasional biotite book is somewhat larger than the average. These larger biotite books are mostly from 1 to 2 inches apart. The color is a clear gray and toward the lighter colored end of the central Texas gray granite series. The granite takes a beautiful polish.

Microscopic description.—The granite is composed predominantly of microcline, quartz, plagioclase, and some biotite. Accessory minerals are rather abundant and consist of titanite, magnetite, apatite, and rutile. The rutile is present as long needles in quartz and is very scarce. Minerals formed by alteration are chlorite and sericite. Much of the biotite is green, indicating some alteration, but little of it has changed to chlorite. Sericite formed by the altering of feldspar is very scarce. The oligoclase is somewhat cloudy especially at the center. The microcline is for the most part clear with some crystals flecked by cloudy areas.

The plagioclase is oligoclase in composition and contains about 80 to 85 per cent of the albite molecule. The estimated mineral composition is microcline 24, plagioclase 38, quartz 33, and biotite 5 per cent. No deleterious minerals were seen. This rock is a soda-potash granite, and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

The grain size averages about 1 mm.. with an occasional microcline crystal attaining as much as 3 mm. in size. The minerals are well interlocked. A small amount of micropegmatite is present. Undulatory extinction is common in the quartz, and some of it has a mosaic-like structure, detectable when near extinction.

Recommendations.—The granite is an excellent stone for building and monumental work. The mineral composition and the size and interlocking arrangement of the grains are such that it is of great strength and will be very durable.

LOCALITY LL–24 (CENTRAL GRANITE COMPANY (NORTON) QUARRY)

Location and geology.—A quarry known as the Norton quarry, now operated by the Central Granite Company, is located 5.2 miles west of Oxford by a road which is mostly unimproved. The highway is hard surfaced from Oxford to the railroad at Llano, a distance of 11.3 miles. The granite was originally hauled northward to Sixmile and then to Llano, a total distance of about 14 miles.

Two sets of vertical joints are present, one of which trends N. 20° W. and the other N. 70° E. Sheeting joints dip about 10° eastward and are parallel to the ground surface. Inclusions are scarce. One large inclusion is present at the south end of the quarry. A few small pegmatites are present. An unusual marking is common which consists of parallel black lines separated by a narrow white zone. These streaks are about one-fourth of an inch wide and are described later. The main quarry is to the north and is about 150 by 150 feet in size and about 20 feet deep to water level. This quarry connects with another one which is not quite so large. Just to the west of the present quarry is a steep hillside of smooth gray granite which would make an ideal quarry site.

Megascopic description.—The granite is even textured and has a grain size of about 2 mm. It is a rather uniformly colored stone with only an occasional very small area slightly deficient in biotite. The color is slightly lighter than the average for the central Texas granites. The granite takes a beautiful polish. A photograph of a polished surface is shown in Plate 4.

Microscopic description.—The granite is composed predominantly of microcline, quartz, and plagioclase, with a small amount of biotite. Accessory minerals are scarce and consist of magnetite, apatite, and a very small amount of zircon and pyrite. Minerals formed by alteration are chlorite and a very small amount of sericite. The biotite has altered in part, going through a stage in which the mineral is green with high birefringence. The final product of alteration is green chlorite having low birefringence. Some of the chlorite has an abnormal lavender interference color. A small amount of sericite has formed as an alteration product of plagioclase. The central portions of zoned plagioclase crystals are very cloudy, and the outer portions may be entirely clear. The microcline is only slightly flecked by alteration products. The plagioclase is oligoclase containing about 80 per cent of the albite molecule. The more basic plagioclase has zonal structure, and carlsbad twins are common. The more acid plagioclase is albite twinned and shows very little evidence of zoning. The estimated mineral composition is microcline 35, quartz 31, plagioclase 30, and biotite 4 per cent. No deleterious minerals were found. The granite is a soda-potash granite, and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

The average grain size is about 2 mm. with a considerable number of grains as much as 3 mm. across. A small amount of micropegmatite is present. The quartz has some undulatory extinction, and a few grains have a mosaic structure detectable near extinction. The quartz exhibits very well the characteristic rows of inclusions so common in the quartz of granite.

A thin section was made including one of the double black lines. Biotite has replaced feldspar to form these lines. Most of the feldspars so replaced have entirely lost their identity and are now a mixture of secondary biotite, albite, and quartz. At the edge of the veins some crystals of microcline and oligoclase are only partly replaced. The light-colored area in the center of these veins is normal granite which has not been altered. The central area is not continuous but is broken up into elongated areas by replacement zones crossing it. These black lines probably originated following a shearing movement sufficient to form zones along which solutions could penetrate.

Recommendations.—The granite is a good building and monumental stone. The mineralogical composition and the interlocking character of the grains are such that the granite is strong and will be very durable. A small amount of pyrite is present. The pyrite has not formed stains on the granite which has been lying about the quarry for years; consequently, it will be safe to use the granite. The black lines will cause some waste in quarrying.

LOCALITY LL–25

Location and geology.—A gray granite quarry located one-half mile north of the Norton quarry (Ll–24) is about 13.5 miles southwest of Llano and about 4.5 miles south of Sixmile. The road from the quarry to Sixmile is in very poor condition. The road from Sixmile to Llano is graded but not hard surfaced. Mr. Parkinson's report on this quarry is as follows: "The quarry is about 100 by 25 feet in area and about 10 feet deep. The stone is clear without noticeable inclusions or veins. In this quarry there are two granites of about the same shade of gray: one is fine grained and the other is rather coarse grained."

Megascopic description.—The granite is slightly porphyritic with phenocrysts of feldspar which range up to about 4 mm. across. The phenocrysts have a slightly pinkish cast, and the groundmass is gray. The groundmass is medium grained and is composed of grains approaching 2 mm. in size. The composite color is medium gray with the faintest trace of pink. The granite takes a beautiful polish. A photograph of a polished surface is shown in Plate 4.

Microscopic description.—The granite is composed predominantly of microcline, quartz, and plagioclase with a small amount of biotite. Accessory minerals are magnetite, apatite, and zircon. Minerals formed by alteration are scarce and consist of a small amount of chlorite and sericite. The biotite has been in part altered, going through a stage in which it is practically colorless with high birefringence. The final alteration product is chlorite. A very small amount of sericite has formed in the more basic oligoclase. The feldspars in general are very little clouded. Some of the more basic oligoclase centers are cloudy, and others are without clouding. The microcline is mostly free of clouding.

The plagioclase is oligoclase in composition and contains about 80 per cent of the albite molecule. Much of the oligoclase is zoned. No deleterious minerals were seen. The estimated mineral composition is microcline 38, plagioclase 36, quartz 22, and biotite 4 per cent. The granite is a soda-potash granite, and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

The average grain size is about 2 mm., with many of the microcline crystals attaining a size of nearly 4 mm. across. A small amount of micropegmatite is present. Much of the quartz has a mosaic structure detectable near extinction.

Recommendations.—The granite is an excellent building and monumental stone. The mineralogical composition, the freshness of the minerals, and the interlocking character of the grains are such that the granite is strong and will be very durable.

LOCALITY LL–26 (HILLTOP QUARRY)

Location and geology.—The Hilltop quarry is located about 1000 feet northwest of the Premier quarry (Ll–40). Mr. Parkinson reports that: "The rock is of an excellent color but contains many inclusions."

Megascopic description.—The granite is medium to fine grained and of very even texture. It is slightly darker than the average central Texas granite. It polishes to a very smooth surface and is probably the clearest, brightest gray of the entire series.

Microscopic description.—The granite is composed predominantly of plagioclase, quartz, microcline, and biotite. Accessory minerals are rather scarce and consist of magnetite, titanite, apatite, and zircon. Minerals formed by alteration are very scarce and consist of chlorite and sericite. The chlorite is an alteration product of biotite. Small flakes of sericite formed from feldspar are scarce. Zonal plagioclase crystals are slightly cloudy at the center, and the rest of the feldspar is clear with only a very few cloudy flecks.

The plagioclase is mostly oligoclase with some overlap into andesine. The albite molecule probably averages about 80 per cent in amount. Typical crystals of zoned plagioclase were examined which have the following range in composition:

Ab_{67} to Ab_{77}—albite, pericline, and carlsbad twinning
Ab_{65} to Ab_{82}—albite twinning
Ab_{77} to Ab_{90}—albite twinning

The zonal structure is more prevalent in the basic types. The more acid plagioclase without zonal structure averages about 85 per cent of albite. The estimated mineral composition is plagioclase 45, quartz 22, microcline 27, and biotite 6 per cent. Small crystals of pyrite are rather common. The granite is a soda-potash granite, and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

The average grain size is about 1.5 mm., with some of the crystals approaching 4 mm. in length. A small amount of micropegmatite is present. The quartz shows some undulatory extinction and some mosaic structure detectable when near extinction.

Recommendations.—The granite is an excellent building and monumental stone. The freshness, mineralogic composition, and interlocking character of the minerals are such that this granite is strong and will be very durable. The only possible feature that might be objectionable in this granite is the presence of fine crystals of pyrite which might in time decompose and stain the surface. However, no evidence of staining is noticed in the rock which has been used. The quarrying costs might be excessive since the granite contains numerous inclusions.

LOCALITY LL–37–GRAY

Location and geology.—A group of gray granite quarries is located about 6.5 miles southwest of Llano along the Cherry Spring road. The road to Llano is graded but not hard surfaced. The granite mass is in a divide area, and the topography is smooth with gentle slopes. The granite exposures, except in the quarries, are rather small, but apparently the soil cover is not over a few feet in thickness at any place between exposures.

The gray granite has in part intruded a pinkish, porphyritic granite. The intrusive relationship is well exposed in the Baldwin quarry which is the northernmost quarry of the group. In this quarry the gray granite crosscuts the pinkish, porphyritic granite, and large blocks of the pinkish, porphyritic granite have been included in the gray granite. The pinkish, porphyritic granite has numerous pegmatite dikes in it. The phenocrysts are pink, and the groundmass is gray. The gray granite is fine grained and of a pleasing color. Both types of stone are being produced from this quarry.

The easternmost quarry of the group, known as the Patterson quarry, is temporarily abandoned. In this quarry much the same relationship is shown as in the Baldwin quarry. Fine-grained gray granite cuts through and includes large blocks of pinkish, porphyritic granite. The northern end of the quarry is not favorable for producing clear stone. The southern end, however, has two very smooth surfaces of good, clear, uniform stone in view. The quarry is about 100 by 50 to 75 feet in size. At the lower edge of the quarry it is about 10 feet to water level. The depth of the quarry bottom below water level is unknown.

Just a few hundred feet to the southwest of the Patterson quarry is the Sullivan quarry which is also temporarily abandoned. The northeastern part of this quarry is about 50 by 50 feet in size and about 5 feet deep to water level. To the southwest is another quarry which is about

50 by 100 feet in size and about 15 feet deep to water level. The two openings are now separated by a pile of waste stone. The northeastern opening contains some inclusions of pinkish, porphyritic granite, and the southwestern opening contains several inclusions of black schist.

The Norton quarry (formerly Gooch and Wells quarry), now active, is located a short distance southwest of the Sullivan quarry. This quarry is in a gray granite in which the inclusions are rather scarce. The few that are present range widely in color. Some of the inclusions are black, and others are nearly white. A few of them are of pinkish, porphyritic granite. A rather large pegmatite dike is visible in the northeastern corner of the quarry. A few narrow pegmatites were seen in the waste material. The main joint direction trends N. 20° E., and another set trends east-west. This quarry is 75 by 75 feet in area and is 50 feet deep. Monumental stone is being produced at present.

Connected with the Norton quarry and to the northwest is the Cassaday Gray Granite Company quarry which is now inactive. In the southwestern corner of the quarry there is a large inclusion of black schist. In this same corner a rib of rock has been left standing. At a distance it looks as if it might be a vertical pegmatite dike. On the western wall of the quarry, where weathering is the deepest, some sheet joints are visible. In general sheet joints are scarce. This quarry is estimated to be 300 by 300 feet in area and about 30 feet deep to water level. Just to the north is another quarry of about the same size which is almost entirely surrounded by waste.

The Blodgett quarry is about 250 feet south of the Norton quarry. The opening is small and only about 20 feet deep. The granite exposed here is very massive and is free of inclusions. It is reported that no sheet joint was encountered in the 20 feet of depth attained.

The westernmost quarry of the group is the Kothe quarry which after a long period of inactivity was reopened in 1941. The opening is about 100 by 50 feet in area and is 10 feet deep. No inclusions were seen. The stone appears to be slightly lighter in color than that seen in the other quarries of the group, and it also appears to be of slightly coarser grain. Weathering has penetrated to a somewhat greater depth, and exfoliation is noticeable on joint blocks near the surface.

Another quarry not belonging to this group, but which is in very similar granite, is located one-half mile to the east. The quarry is about 175 by 100 feet in area and about 10 feet deep to water level. A large block of schist is exposed on the south quarry wall, but in general inclusions are scarce. Sheeting is poorly developed. Pegmatites are very scarce. A few very narrow, vein-like mylonites are present.

Megascopic description.—The granite is medium gray, even textured, uniform grained, and is composed of grains up to about 2 mm. across. The color is about an average of that found in central Texas and varies slightly throughout the quarry group, the rock from the Baldwin quarry being slightly darker than that from the Cassaday-Norton group. If the central Texas granites are placed in a series graded uniformly from light to dark, the granites of this group are closer to the same color than to the nearest approaching granite elsewhere in central Texas. This granite takes a beautiful polish. A photograph of a polished surface is shown in Plate 4.

Microscopic description.—The granite is composed predominantly of microcline, quartz, plagioclase, and some biotite. Accessory minerals are rather scarce and consist of magnetite, titanite, apatite, and a very small amount of zircon. Minerals formed by alteration are chlorite and sericite. Alteration products are scarce and consist of chlorite formed from biotite and sericite formed from feldspar. The zonal oligoclase is cloudy at the center and clear at the border. The rest of the feldspars are flecked by cloudy areas.

The plagioclase is oligoclase in composition and contains an average of about 80 per cent of the albite molecule. Zonal structure is common, but the range in albite content is rather small, being mostly less than 5 per cent. The estimated mineral composition is microcline 26, quartz 30, plagioclase 38, and biotite 6 per cent. No deleterious minerals were seen.

The average grain size is about 2 mm. with many crystals 3 mm. across. Some micropegmatite is present. The quartz has undulatory extinction and some mosaic structure detectable when near extinction.

Chemical composition.—Two analyses are available of this granite (see Table 7). One (A)[26] is by the Bureau of Industrial Chemistry of The University of Texas, and the other (B) is by S. S. Goldich,[27] of Texas Agricultural and Mechanical College, who in a recent study of the granites of this region has made several analyses.

Table 7. Chemical analyses of Sixmile granite.

	(A) Per cent	(B) Per cent
SiO_2	70.20	72.15
Al_2O_3	17.36	14.24
Fe_2O_3	1.32	0.84
FeO	1.90	1.74
MgO	0.20	0.64
CaO	1.46	1.39
Na_2O	4.30	3.73
K_2O	2.90	4.55
H_2O+	0.70	0.30
H_2O-		0.04
CO_2	tr.	0.06
TiO_2	--------	0.33
P_2O_5	0.06	0.08
MnO	tr.	0.05
BaO	--------	0.05
F	none	--------
S	--------	tr.
	100.40	100.19
Sp.gr. t°/4°	--------	2.659

(A) Gray granite, Llano County, Bradshaw quarry. Sampled by G. A. Parkinson. Analysed 1904 by O. H. Palm.
(B) Gray granite, Llano County, Cassaday quarry. Analyst, S. S. Goldich.

The normative mineral composition has been calculated for (A) and quoted for (B). In addition the modal mineral composition has been determined. (See Table 8.)

Table 8. Normative and modal mineral composition of Sixmile granite.

	Norm (A) Per cent	Norm (B) Per cent	Mode Per cent
Quartz	29.69	28.71	30
Orthoclase	17.12	26.69	36
Albite	36.42	31.44	38
Anorthite	6.82	6.13	
Corundum	4.52	0.92	
Hypersthene	2.89	3.71	
Magnetite	1.92	1.16	
Ilmenite	----	0.61	
Apatite	0.15	0.20	
Calcite	----	0.14	
Pyrite		trace	
Biotite		----	6
Normative plagioclase		$Ab_{85}An_{15}$	
Symbol		1.4."2.3.	

[26]Schoch, E. P., Chemical analyses of Texas rocks and minerals: Univ. Texas Bull. 1814, Anal. 1208, p. 186, 1918.
[27]Goldich, S. S., Evolution of central Texas granites: Jour. Geol., vol. 49, p. 700, 1941.

Analysis (A) is an inferior analysis as can readily be seen by inspection of the above normative and modal mineral composition. The corundum is abnormally high for an igneous rock. Furthermore the lack of agreement between the normative and modal orthoclase and plagioclase (albite plus anorthite) is quite marked. On the other hand, analysis (B) is an exceptionally good analysis, showing a low corundum content and a very good agreement between the normative and modal feldspars. The granite is a soda-potash granite, and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

The chemical analysis shows that this granite is an exceptionally good building stone. Sulphur is present as a trace, indicating that pyrite cannot be present in more than a trace. The calcite contained in this granite is low; consequently, there will be no tendency for the stone to disintegrate because of calcite weathering.

Recommendations.—The granite is an excellent building and monumental stone. The mineral composition, the freshness, and the interlocking character of the minerals are such that this granite is very strong and durable. There are two active quarries in this group and several others that could be easily operated upon the installation of machinery. A very large amount of granite remains.

LOCALITY LL-37-PORPHYRITIC

Location and geology.—The location and description of this quarry are given on page 35. Porphyritic granite is being produced in the Baldwin quarry and is exposed in the Patterson quarry. The granite is transitional in appearance between the gray and pink granites. It has numerous pink pegmatite veins traversing it. Flow structure is well developed, and in certain directions this structure appears wavy, giving a very pleasing appearance to the stone.

Megascopic description.—The granite takes a good polish. Pink feldspar crystals averaging about 15 mm. in length make up about 30 per cent of the stone. The rest of the rock between the pink feldspars is medium to dark gray, medium grained, and is composed of recognizable quartz, biotite, and cloudy to clear feldspars. Some pyrite and considerable magnetite are present. The granite is intermediate in color between the true gray granites and the true pink granites.

Microscopic description.—The granite is composed predominantly of microcline, quartz, and plagioclase with some biotite and hornblende. Accessory minerals are titanite, magnetite, apatite, and zircon. A small amount of pyrite and an occasional flake of biotite containing rutile are present, and pleochroic halos are rather abundant. Minerals formed by alteration are chlorite and green biotite, both formed from brown biotite. The feldspars are mostly clear with only occasional cloudy flecks. A few of the more basic plagioclases are mostly cloudy.

The plagioclase is oligoclase and is rather uniform in composition, containing about 80 per cent of the albite molecule. Zonal feldspars are not well developed. The estimated mineral composition is microcline 29, plagioclase 35, quartz 29, biotite 6, and titanite 1 per cent. The grain size of the granite is too large to make an entirely satisfactory estimate of the percentages of the minerals present. The above estimate probably states too low a percentage for microcline and too high a percentage for the other minerals since the large microcline phenocrysts were not well represented in the thin sections. The granite is a soda-potash granite, and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

The average grain size of the gray portion of the stone is about 2.5 mm., and the phenocrysts of pink feldspars average about 15 mm. in length. Some micropegmatite is present. The quartz has undulatory extinction and a mosaic structure detectable when near extinction.

Recommendations.—The granite was originally discarded and only the fine-grained gray granite from the quarry utilized. The attractiveness of this granite led users of the fine-grained gray granite to purchase occasional blocks of the porphyritic stone. The porphyritic granite has increased in favor until all of the usable stone produced is sold. A large amount of the granite is available, but considerable waste will be caused by the numerous pegmatites in it. Some pyrite is present. It has not been determined whether or not this pyrite decomposes, producing unsightly stains. The granite is strong and in any event will be of value.

LOCALITY LL–39 (PREMIER AND TEMPLETON QUARRIES)

Location and geology.—A large gray granite mass located about 6 miles west of Llano and 1 mile south of the Llano-Mason road is 7.5 miles from the nearest railroad, which is at Llano. The road from the quarries to the highway is unimproved, and the highway is graded but not surfaced. Two quarries in the same granite mass are within a few hundred feet of each other.

The granite is well exposed on the side of a hill and is without overburden except for some residual boulders. The granite is fine grained and is bluish gray. The Templeton quarry is about 50 by 75 feet in size and is about 40 to 50 feet deep. Two prominent sets of joints are present: one, which is parallel to the "easy way," trends N. 50° E., and the other trends N. 40° W. A few other joints were noticed trending in other directions. No sheeting structure was seen. A very few inclusions are present. Along the joints the rock is discolored for about 6 inches. These "sap" zones follow the joints to the bottom of the quarry; however, the joints are so widely spaced that little rock is lost because of "sap."

The Premier quarry is a few hundred feet west of the Templeton quarry. It is about 60 by 90 feet in area and about 50 feet deep. The rock and its structure are entirely similar to those of the Templeton quarry except that inclusions are not as numerous. Both of these quarries appear to be equipped to handle large-sized blocks of stone.

Megascopic description.—The granite is of uniform texture, fine grain, and very light gray. The biotite is of a fairly uniform size of about 1 mm. and is rather evenly distributed. The granite takes a very good polish. A photograph of a polished surface is shown in Plate 4.

Microscopic description.—The granite is composed predominantly of microcline, quartz, and plagioclase with some biotite. Accessory minerals are magnetite, titanite, and apatite. Minerals formed by alteration are chlorite and sericite. Alteration of biotite is rather common with the formation of green biotite which in many places alternates with zones of brown biotite. The final product of this alteration is chlorite. Sericite has formed in the centers of some of the zoned oligoclase crystals. The centers of the zoned oligoclase are cloudy, and the exteriors are for the most part clear. The microcline is flecked by cloudy areas.

The plagioclase is oligoclase in composition and averages about 85 per cent albite. Zonal plagioclase is present, and measurements on two crystals gave a range in the albite molecule from Ab_{80} to Ab_{87} and Ab_{82} to Ab_{90}. Some of the microcline has carlsbad twinning. The estimated mineral composition is microcline 31, quartz 34, plagioclase 31, and biotite 4 per cent. No deleterious minerals were seen. The granite is a soda-potash granite, and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

Recommendations.—The granite is an excellent building and monumental stone. The mineral composition, the freshness of the minerals, and the interlocking character of the grains are such that the granite is very strong and durable.

LOCALITY LL–40 (PREMIER AND SCHLAUDT QUARRIES)

Location and geology.—The Premier and Schlaudt quarries are located about 12 miles southwest of Llano, and about 2.7 miles south of Sixmile, which is on the Llano-Cherry Spring road. The road from the quarries to Sixmile is unimproved, and the road from Sixmile to Llano is graded but not hard surfaced.

The granite mass is on a divide, the sides of which slope steeply. The northern quarry of the group is the Premier, which is now inactive. The waste has been piled close to the edge of the quarry, and it will be impossible to continue operations until it is removed. The quarry is several hundred feet across and about 30 feet deep to water level. The water is a beautiful, clear green and appears to be many feet deep. Inclusions are scarce especially in the lower part of the exposed rock. Near the top of the west wall is a large inclusion of gneiss. Sheeting is well developed parallel to the slope of the surface.

South of the Premier a few hundred feet is the Schlaudt quarry, now inactive. This quarry has been heavily "blasted" and is in bad condition. Considerable work will be necessary to develop a good quarry face. The granite at the bottom of the quarry is almost free of inclusions. Near the surface, however, there are many inclusions of gneiss and schist. The main joints trend N. 70° E. and N. 40° W. A few pegmatites are present. A large amount of stone can be quarried in this area.

About a mile north of the Premier quarry a small gray granite quarry, first opened in 1895, was reopened in 1938. The mass of gray granite is rather small, and one side of the quarry is already in schist. No inclusions were seen, and only a few pegmatites are present. The stone is of a good grade.

Megascopic description.—The granite is even textured, medium grained, and composed of grains up to about 2 mm. across. The granite is a clear gray and is about the average color of the gray granites exposed in central Texas. It polishes well and has been sold under the trade name "Premier blue."

Microscopic description.—The granite is composed predominantly of plagioclase, microcline, quartz, and biotite. Accessory minerals are magnetite and a very small amount of apatite and zircon. A few pleochroic halos are present in the biotite. Minerals formed by alteration are chlorite and sericite. Some of the biotite has partially altered to a nearly colorless mineral with high birefringence. The final product of alteration is green chlorite. Some of the basic centers of the plagioclase have altered to sericite. The centers of the zoned plagioclase are cloudy, and the borders are mostly clear. The microcline is mostly clear or only slightly flecked with cloudiness.

The plagioclase is mostly oligoclase in composition with a small amount of andesine at the centers of some zonal crystals.

The non-zoned plagioclase contains about 80 per cent of albite. The estimated mineral composition is plagioclase 43, microcline 26, quartz 26, and biotite 5 per cent.

The grain size averages about 1.5 mm. with an occasional microcline crystal as much as 3 mm. in size. Micropegmatite is very scarce. Some of the quartz has undulatory extinction, and some has a mosaic structure detectable when near extinction.

Chemical composition.—An analysis of this granite, made by the Bureau of Industrial Chemistry of The University of Texas,[28] is given in Table 9 which also includes normative mineral composition calculated from the analysis and the mode for comparison.

Table 9. Premier granite.

Chemical analysis	Per cent	Mineral composition	Norm (Per cent)	Mode (Per cent)
SiO_2	72.80	Quartz	43.50	26
Al_2O_3	15.40	Orthoclase	13.62	26
Fe_2O_3	2.15	Albite	22.86	43
FeO	0.40	Anorthite	7.62	
MgO	1.00	Corundum	5.63	
CaO	1.60	Hypersthene	2.50	
Na_2O	2.70	Magnetite	1.29	
K_2O	2.30	Apatite	0.12	
H_2O+	0.45	Hematite	1.26	
P_2O_5	0.05	Biotite	----	5
	98.85			

The summation of the analysis is low, the norm and mode do not agree, and the norm for corundum is too high, suggesting that this is an inferior analysis. The full amount of potash and soda is apparently not revealed. The granite is a soda-potash granite, and since the chief femic mineral is biotite it may be further distinguished by the name granitite.

Recommendations.—The granite is an excellent building and monumental stone. The average grain size, the interlocking character of the minerals, and the mineralogical composition are such that the granite is very strong and durable.

LOCALITY LL–52

Location and geology.—About 5 miles southwest of Llano three small openings have been made in pinkish-gray granite. The deposit is 1 mile south of the Llano-Cherry Spring road. The granite has a slightly pinkish cast, probably due to surface weathering. The granite appears to become more gray with depth, and does not contain inclusions. A few veins contain pyrite, but pyrite was not seen in the granite itself. The granite mass is between one-fourth and one-half mile in length and appears to have enough width to warrant the development of a quarry. The surface, underlain by granite, is gently sloping, and many large boulders, remnants of weathering, lie upon the surface.

Megascopic description.—The granite is medium grained and of rather even texture. The biotite is evenly distributed in a rock composed chiefly of pinkish feldspars and clear quartz. The granite is definitely pinkish gray and has so much pink in it that it cannot be directly compared with the other gray granites. The sample examined is from near the surface, and it appears that with depth the color will be medium gray, similar to that described under Ll–37 which is located a short distance to the southwest. The granite takes an excellent polish.

Microscopic description.—The granite is composed predominantly of microcline, quartz, and plagioclase with some biotite. Accessory minerals are very scarce and consist of magnetite, titanite, apatite, and zircon. Minerals formed by alteration are chlorite and sericite. A small amount of biotite has altered to chlorite. A small amount of sericite has formed in some of the more basic oligoclase. The zoned oligoclase is mostly cloudy in the center and clear at the border. A few of the zoned oligoclase crystals, however, have clear centers and clear borders, which are separated by a cloudy zone. The microcline is very clear with only small flecks of cloudiness.

The plagioclase is oligoclase in composition containing about 84 per cent of the albite molecule. A zoned oligoclase crystal examined ranges in composition between Ab_{80} at the center and Ab_{85} at the border. Zonal oligoclase is common as well as fresher-appearing, albite-twinned oligoclase without zoning. The estimated mineral composition is plagioclase 32, quartz 31, microcline 33, and biotite 3 per cent.

[28] Schoch, E. P., Chemical analyses of Texas rocks and minerals: Univ. Texas Bull. 1814, Anal. 1212, pp. 72, 187, 1918.

No deleterious minerals were found. The granite is a soda-potash granite, and since the chief femic mineral is biotite, it may be further distinguished by the name granitite.

Recommendations.—The granite will be suitable for building and monumental stone if the color becomes uniform with depth. The mineralogical composition and the size and interlocking arrangement of the grains are such that the granite is strong and durable.

LOCALITY LL–65 (CURLEY QUARRY)

Location and geology.—The Curley quarry was opened many years ago and is located just south of the Valley Spring road 7 miles west of Llano. The granite is almost free of inclusions and pegmatites and is a sound rock. The outcrop stands above the surrounding flat area about 5 feet, and several acres of stone is present. The granite varies in color from light gray to light pink, and it is impossible to obtain any quantity of stone of uniform color. If a sufficient depth were reached, the granite would probably be of a uniformly gray color. The near-surface material seems to be the pinkest with a decrease of pinkness with depth. This color has probably been produced by weathering.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, and quartz present in about equal amounts and about 3 per cent of biotite. Accessory minerals are magnetite and apatite. A small amount of reticulated quartz is present containing long, slender needles of rutile and plates of ilmenite. Minerals formed by alteration are chlorite produced from biotite and sericite from plagioclase. The plagioclase is oligoclase in composition. Much of the oligoclase shows zonal growth, the central, more basic parts being cloudy. The borders are either clear or flecked by cloudiness. The microcline is mostly clear with occasional cloudy flecks. No deleterious minerals were seen. The granite is a soda-potash granite, and since the predominant femic mineral is biotite, it may be further distinguished by the name granitite. The average grain size is about 1.5 mm. The quartz has undulatory extinction and has some mosaic structure detectable when near extinction.

Recommendations.—The mineral composition and the interlocking character of the grains are such that this is a strong and durable granite. As already noted, it varies in color between grayish and pink and gray. It is impossible to obtain a uniformly colored product; consequently, this rock is not in demand.

LOCALITY LL–66 (STRIBLING QUARRY)

Location and geology.—About 4 miles south of Llano and about one-half mile east of the Fredericksburg road, a quarry has been opened in a medium-grained, gray granite. The granite is of a beautiful, fresh gray color, but unfortunately pyrite is scattered throughout the rock. The pyrite oxidizes rapidly, and rust stains spread from each pyrite grain. In a short time the exposed granite becomes unsightly.

Microscopic description.—The granite is composed predominantly of microcline, quartz, plagioclase, and biotite. Accessory minerals are very scarce and consist of apatite and zircon. A few pleochroic halos were seen in some of the biotites. A small amount of reticulated quartz is present containing long slender needles of rutile and plates of ilmenite. Chlorite and sericite are very scarce. The plagioclase is oligoclase in composition. Both the oligoclase and the microcline are very cloudy. Only rarely are some of the borders of the zoned oligoclase crystals clear. The granite is rather too coarse grained to estimate the mineral content closely with a limited number of slides. A rough estimate is microcline 47, quartz 28, plagioclase 21, and biotite 4 per cent. Pyrite was not present in the thin sections, but many specks and areas of it were found in the quarry waste. The average grain size is about 3 mm., and the granite is composed of rather uniform-sized grains. The quartz has some undulatory extinction.

Recommendations.—Even though this granite is strong and durable, the presence of pyrite specks and nodules which weather, forming spots and streaks on the surface, makes it valueless as an exterior building or monumental stone.

LOCALITY LL-67 (KANSAS CITY QUARRY)

Location and geology.—Two miles west of Llano, just north of the Mason road, a coarse-grained gray granite has been quarried. This is a very pleasingly colored dark gray granite when first quarried. Some black inclusions, composed essentially of tourmaline, are present. The granite contains small areas in which pyrite is strongly concentrated. These areas are rather widely spaced, but upon weathering a rusty stained streak forms below the pyrite. Some of these streaks on quarry blocks are at least 18 inches long. Because of the pyrite this stone is of no value, either as a building or monumental stone.

Microscopic description.—The granite is composed predominantly of microcline, quartz, plagioclase, biotite, and a small amount of muscovite. Accessory minerals are very scarce and consist of magnetite, apatite, and zircon. A few pleochroic halos were seen in the biotite. Sericite and chlorite are rather common alteration products. The plagioclase is oligoclase in composition. Both the oligoclase and the microcline are flecked by cloudy areas. The granite is too coarse grained to obtain, with a limited number of slides, an accurate estimate of the amounts of the various minerals present. A rough estimate is quartz 46, microcline 37, plagioclase 14, and biotite 3 per cent. For the rock as a whole the quartz estimate appears to be too high. Pyrite was not found in thin section, but many areas of it were found in the quarry waste. The average grain size is about 3.5 to 4 mm., and this is the coarsest-grained gray granite examined. The quartz has undulatory extinction and has some mosaic structure detectable when near extinction.

Recommendations.—Even though the granite is strong and durable, the presence of pyrite which weathers, forming streaks on the surface, makes it valueless as an exterior building or monumental stone.

Mason County

LOCALITY M-6 (BLODGETT QUARRY)

Location and geology.—The Blodgett quarry is located 4.5 miles south of Pontotoc in Mason County and about 1 mile from the Llano County line. The quarry is about 26.5 miles from the nearest railroad, which is at Llano. The first 14.5 miles of the road is mostly graded but is otherwise unimproved. The last 12 miles from Valley Spring to Llano is well graded but not hard surfaced.

The granite is in a rather flat area. It is a fine-grained, uniform-textured gray granite which contains a few inclusions. A half-inch pegmatite vein containing pink feldspar trends N. 80° E. and dips northward at about 45°. The most prominent set of joints trends N. 55° E., and another set trends N. 45° W. Sheeting structure was not seen. The quarry is rather small in area and not over 10 feet deep.

Megascopic description.—The granite is fine grained and of an even texture. The biotite is of uniform size and distribution. The color is slightly lighter than the average for the central Texas granites. It is a bright gray granite which takes a beautiful polish. A photograph of a polished surface is shown in Plate 4.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, and quartz with some biotite. Accessory minerals are very scarce and consist of magnetite, apatite, and perhaps zircon. A few pleochroic halos were noticed in some of the biotite. Minerals formed by alteration are chlorite and sericite. The chlorite is an alteration product of biotite. A very small amount of sericite is present in some of the oligoclase. The oligoclase is cloudy with some zones more cloudy than others. The microcline is mostly clear with only occasional flecks of cloudiness. The plagioclase is oligoclase in composition, containing about 80 per cent of the albite molecule. The estimated mineral composition is microcline 35, quartz 31, plagioclase 29, and biotite 5 per cent.

The average grain size is about 1 mm. with very few crystals attaining a size of 3 mm. The grains are very well interlocked, and some micropegmatite is present. Much of the microcline contains rounded areas of quartz as if the quartz had started to crystallize and had then been enclosed by microcline crystals. The quartz has some undulatory extinction.

Chemical composition.—The following analysis was made by the Bureau of Industrial Chemistry of The University of Texas.[29] The normative mineral composition calculated from the analysis and the mode for comparison are also given in Table 10.

Table 10. Blodgett quarry granite.

Chemical analysis	Per cent	Mineral composition	Norm (Per cent)	Mode (Per cent)
SiO_2	78.00	Quartz	40.86	31
Al_2O_3	12.35	Orthoclase	25.30	35
Fe_2O_3	1.30	Albite	28.80	29 (Albite and Anorthite together)
FeO	-------	Anorthite	0.50	
CaO	0.15	Corundum	1.83	
MgO	0.60	Hypersthene	1.50	
Na_2O	3.40	Magnetite	none	
K_2O	4.34	Apatite	0.09	
P_2O_5	0.04	Hematite	1.30	
H_2O	0.20	Biotite		5
	100.38			

The norm and the mode do not agree, suggesting that this is an inferior chemical analysis. The granite is a soda-potash granite, and since the chief femic mineral is biotite, the rock may be further distinguished by the name granitite.

Recommendations.—The granite is an excellent building and monumental stone. The mineral composition, the grain size, and the interlocking character of the minerals are such that the granite is extremely strong and durable.

LOCALITY M-23 (KING MOUNTAIN QUARRY)

Location and geology.—A quarry recently opened about 1 mile south of the Blodgett quarry is 25.7 miles from the nearest railroad, which is at Llano. The first 13.7 miles of the road is mostly graded but otherwise unimproved. The last 12 miles from Valley Spring to Llano is well graded but not hard surfaced. The granite has been named the King Mountain granite mass, and the quarry is known as the King Mountain quarry. King Mountain, however, is shown on the Llano quadrangle about 3 miles southeastward in Llano County and is an entirely separate and distinct topographic feature.

The granite mass is the largest and most impressive of all the gray granites seen in central Texas. Many acres of granite are exposed south of the quarry, without any surficial debris except a few residual boulders. The granite surface is smooth and very similar to that so common on the pink granites of central Texas. The granite surface slopes from the quarry southward. Not an inclusion was seen upon this surface or in the quarry. Pegmatite veins are extremely rare. One, which is 2 inches thick, trends N. 40° E. and dips northwestward at an angle of 30°. Two widely spaced joint sets trend N. 40° E. and N. 45° W. Along a few of these joints thin seams of mylonite are present. In the quarry, which is about 40 by 75 feet in area and 10 feet deep, not a blemish was seen except for one quartz vein about one-half inch in thickness. A small amount of discolored stone is present along the joints at the south end of the quarry. A 200-foot cliff of this granite is exposed northeastward from the quarry.

Microscopic description.—The granite is composed predominantly of microcline, quartz, and plagioclase, with a small amount of biotite. Accessory minerals are rather scarce and consist of magnetite, apatite, and perhaps zircon. A few pleochroic halos were seen in some of the biotites. Minerals formed by alteration are chlorite and sericite. The biotite has altered in a rather peculiar manner going through a stage in which it is almost colorless. The final product is chlorite. A small amount of sericite has formed in some of the more basic plagioclase crystals. The plagioclase is mostly cloudy, and the microcline is mostly clear with a few small flecks of cloudiness.

The plagioclase is oligoclase in composition and contains about 80 per cent of the albite molecule. Zonal plagioclase is common. The estimated mineral composition is microcline 33, plagioclase 32, quartz 30, and biotite 5 per cent. No deleterious minerals were found. The granite is a soda-potash granite, and since the chief femic mineral is biotite, the rock may be further distinguished by the name granitite.

The average grain size is about 1 mm. with the maximum size slightly more than 2 mm. across. The grains are well interlocked. A small amount of micropegmatite is present. Many of the microcline

[29]Nash, J. P., Texas granites: Univ. Texas Bull. 1725, p. 7, analysis 10 [9], 1917.

crystals enclose rounded quartz particles as if the quartz had begun to crystallize and then was included by the growing microcline crystals. The quartz has some undulatory extinction.

Chemical analysis.—A chemical analysis of the King Mountain granite and the normative mineral composition as calculated from the analysis are given in Table 11.

Table 11. King Mountain granite.

Chemical analysis	Per cent	Normative mineral composition	Per cent
SiO_2	73.16	Quartz	29.76
Al_2O_3	14.49	Orthoclase	30.02
Fe_2O_3	0.45	Albite	28.82
FeO	1.08	Anorthite	6.95
MgO	0.39	Corundum	0.82
CaO	1.51	Hypersthene	2.19
Na_2O	3.43	Magnetite	0.70
K_2O	5.09	Ilmenite	0.46
H_2O+	0.17	Apatite	0.14
H_2O-	0.03	Fluorite	0.07
CO_2	0.05	Calcite	0.11
TiO_2	0.18	Pyrite	0.02
P_2O_5	0.06		
MnO	0.03	Normative plagioclase	$Ab_{81}An_{19}$
BaO	0.07	Symbol 1.4.″2.3.	
F	0.03		
S	0.01		
	100.23		
Less O	0.02		
	100.21		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysts: R. B Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

The chemical analysis shows that this is a very good granite.

Recommendations.—The granite is an excellent building and monumental stone, and an unlimited quantity of it is present. The mineralogical composition of the granite and the size and interlocking arrangement of the grains are such that it is of very great strength and durability. The distance which the granite must be hauled to a railroad may limit the extensive development of the deposit.

RED AND PINK GRANITE

Resumé.—Commercially important pink granites are present in at least five and possibly six counties of central Texas. The most accessible deposits are in Burnet, Gillespie, and Llano counties, and many others are present in Mason and Blanco counties. The large Katemcy granite mass extends into McCulloch County where exfoliation domes of granite favorable for quarrying may exist. The pink granites are so extensive and in general are in such large masses that it was deemed necessary to cover only the more important types and occurrences. Detailed maps have not been made of these deposits. A program for mapping the Central Mineral region of Texas is in progress, and eventually maps covering all the granites will be available.

The granites are composed predominantly of microcline, plagioclase, quartz, and biotite. About one-third of them contain hornblende, three contain minor amounts of muscovite, and four contain very small amounts of augite. Of the accessory minerals, magnetite is present in all except one, and if sufficient thin sections were made of this granite, magnetite undoubtedly would be found. Titanite is present in about half of the granites, and apatite was detected in more than 80 per cent of them. Fluorite is a common accessory mineral and is present in more than half of the granites. Zircon is almost invariably present. Rutile and ilmenite are associated in reticulated quartz which is present in at least 17 of the granites. Allanite was found in one-third of the granites. This mineral in all except one granite has changed in part to an isotropic mineral and in part to a cryptocrystalline mineral. Allanite may be more widely present than indicated since it is sparsely distributed, and in many cases only two to four thin sections of each granite were examined.

The plagioclase is mostly oligoclase in composition. The composition of the plagioclase was mostly determined from the optical properties of crystals oriented by the aid of a universal stage. Many of the granites are of about the same composition, and in several samples the predominant type of feldspars was determined by ordinary examination without the aid of the universal stage.

Sericite and chlorite, minerals formed by alteration, are present in various amounts. Secondary albite was found in one hydrothermally altered granite. Calcite is present in the same granite, and an objectional amount was also found in two other granites.

Table 12 lists the granites examined and shows the minerals contained in each granite. In the last column of this table, the mass from which the granite was obtained is given, or when the granite is from smaller unnamed masses, the type of granite is given instead. The mineral composition of the granites gives very little in-

Table 12. Mineral composition of central Texas pink and red granites.

Sample	Microcline	Plagioclase	Quartz	Biotite	Hornblende	Muscovite	Augite	Magnetite	Titanite	Apatite	Fluorite	Zircon	Rutile	Ilmenite	Sericite	Chlorite	Albite	Calcite	Reticulated quartz	Allanite	Granite mass or type
Bl–1	x	x	x	x				x			x	x			x	x					Medium grained
Bl–7	x	x	x	x				x			x	x			x	x					Medium grained
Bl–8	x	x	x	x				x			x	x	x		x	x					Medium grained
Bl–9	x	x	x	x	x			x		x		x			x	x					Medium grained
Bl–11	x	x	x	x				x	x	x	x	x			x	x	x	x			Grape Creek mass
Bl–15	x	x	x	x	x			x		x		x			x	x					Grape Creek mass
Bu–5	x	x	x	x	x			x	x	x		x	x	x	x	x			x	x	Granite Mountain mass
Bu–6	x	x	x	x	x			x	x	x		x	x	x	x	x			x		Granite Mountain mass
Bu–9	x	x	x	x				x		x	x	x	x	x	x	x			x		Granite Mountain mass
Bu–12	x	x	x	x	x			x	x	x		x	x	x	x	x			x		Granite Mountain mass
Bu–13	x	x	x	x	x			x	x	x		x	x	x	x	x			x		Granite Mountain mass
G–11	x	x	x	x				x		x	x				x	x					Medium grained
G–15	x	x	x	x	x			x	x	x	x	x	x		x	x					Enchanted Rock mass
G–16	x	x	x	x				x		x	x	x	x	x	x	x			x		Medium grained
Ll–12	x	x	x	x				x	x	x	x	x	x	x	x	x			x		Granite Mountain mass
Ll–13	x	x	x	x				x	x	x	x	x			x	x					Enchanted Rock mass
Ll–14	x	x	x	x	x			x	x	x	x	x			x	x					Lone Grove mass
Ll–16	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x			x	?	Lone Grove mass
Ll–23	x	x	x	x	x			x	x	x		x			x	x		x			Wolf Mountain phacolith
Ll–28	x	x	x	x	x		x	x	x	x	x	x			x	x		x		x	Enchanted Rock mass
Ll–29	x	x	x	x	x			x	x	x		x			x	x				x	Enchanted Rock mass
Ll–30	x	x	x	x				x	x	x		x			x	x					Enchanted Rock mass
Ll–31	49	27	21	3				x		x					x	x				x	Fine grained
Ll–32	40	33	26	0.4				x		x		x			x	x					Medium grained
Ll–33	41	27	31	1				x				x			x	x					Fine grained
Ll–35	x	x	x	x•		x		x		x	x	x			x	x					Llanite
Ll–36	x	x	x	x	x			x	x	x		x	x	x	x	x			x	x	Lone Grove mass
Ll–41	25	37	37	1				x				x			x	x					Fine grained
Ll–43	x	x	x	x	x			x	x	x		x	x	x	x	x			x	x	Lone Grove mass
Ll–44	x	x	x	x	x		x	x	x	x		x	x	x	x	x			x		Granite Mountain mass
Ll–45	36	27	34	3				x		x		x			x	x					Oatman granite
Ll–62	25	30	42	3				x		x		x			x	x				x	Fine grained
Ll–63	x	x	x	x				x		x	x	x	x	x	x	x			x	x	Enchanted Rock mass
M–3	30	40	29	1		x					x	x			x	x					Fine grained
M–4	x	x	x	x				x	x	x		x	x	x	x	x		x	x	x	Katemcy mass
M–5	x	x	x	x			x	x			x	x			x	x				x	Katemcy mass
M–7	x	x	x	x				x		x		x			x	x					Grit mass
M–9	x	x	x	x				x	x	x	x	x	x	x	x	x			x	x	Katemcy mass
M–11	x	x	x	x				x		x	x	x	x	x	x	x			x		Katemcy mass
M–12	x	x	x	x				x			x	x	x	x	x	x			x	x	Katemcy mass
M–16	x	x	x	x	x			x		x	x	x			x	x		x		x	Medium grained
M–17	x	x	x	x				x		x	x	x			x	x					Katemcy mass
M–19	x	x	x	x	x			x	x	x	x	x	x	x	x	x			x	x	Katemcy mass

formation about their relative ages. Hornblende is more common in the Town Mountain type granite than it is in the other types of granite. The Katemcy granite, however, which is probably a Town Mountain granite has very little hornblende in it. Flourite is less common in the fine-grained granites than it is in the other types. Titanite is practically confined to the Town Mountain types.

The granites contain a large amount of soda-lime feldspars in addition to the preponderant microcline and are soda-potash granites. Many of the granites are biotite granites known as granitites, and others are biotite-hornblende granites.

Physical tests for the central Texas pink granites will be given in a separate chapter. They were not completed in time to be included under each locality described.

In Table 13 the grain size of the granites is given. The table also gives the distance that the granites are located from the nearest railroad and the name of the property

Table 13. Location and grain size of central Texas pink and red granites.

County	No.	Name of quarry, property,[a] or topographic feature	Granite mass or type	Grain size[b] *Mm.*	Distance from railroad *Miles*
Blanco	1	Watson property	Medium grained	7	25†
	7	Schmidt property	Medium grained	7	26†
	8	Maurer and Reagan property	Medium grained	8	22†
	9	Klett property	Medium grained	10	30
	11	Gourley property	Grape Creek mass	8(23)40	24
	15	Coleman property	Grape Creek mass	8(23)40	23
Burnet	5	Texas Pink Granite Company	Granite Mountain mass	6(19)35	0
	6	Kennison Rock	Granite Mountain mass	6(18)30	3
	9	Edmans property	Granite Mountain mass	7(19)35	0.5
	12	Phillips property (Hog Mtn.)	Granite Mountain mass	8(26)40	2.5
	13	Phillips property (Anderson Rock)	Granite Mountain mass	8(24)40	3.5
Gillespie	11	Nagel Bros. quarry (Bear Mtn.)	Medium grained	5	4.5†
	15	Sagebiel property	Enchanted Rock mass	7(18)35	20†
	16	Smith property	Medium grained	6	17†
Llano	12	Petrick Granite Company	Granite Mountain mass	4(13)20	0
	13	Runge property	Enchanted Rock mass	7(19)30	25
	14	Kingsland Granite Company	Lone Grove mass	8(23)35	0
	16	Behrns property	Lone Grove mass	3(11)20	8
	23	Scaholm property (Town Mtn.)	Wolf Mountain phacolith	4(14)30	2
	28	Moss property	Enchanted Rock mass	7(20)30	21
	29	Rusche property	Enchanted Rock mass	2(12)25	21
	30	Moseley property	Enchanted Rock mass	5(17)40	22
	31	Cassaday property	Fine grained	1.5	6.5
	32	Ratliff property	Medium grained	5	9.5
	33	Cone property	Fine grained	2	7.5
	35	Haynes property	Llanite dike	M*(3)6	3.5
	36	Premier Granite Company	Lone Grove mass	8(22)40	1
	41	Sandstone Mountain	Fine grained	2.5	4
	43	Fitzsimons Land and Cattle Co.	Lone Grove mass	7(21)30	?
	44	Craig property	Granite Mountain mass	2(13)20	0.5
	45	Stribling property (Sharp Mtn.)	Oatman granite	3	5
	62	Cone property (Hickory Mtn.)	Fine grained	2	7.5
	63	Moss property (Enchanted Rock)	Enchanted Rock mass	5(17)30	23.5
	68	Kingsland Granite Company	Lone Grove mass		0
	69	Stewart property	Medium grained	-- ---	4.5
Mason	3	Eppler property	Fine grained	3	35
	4	Elebracht and Lindsay property	Katemcy mass	5(26)55	24.5
	5	Katemcy Granite mass	Katemcy mass	6(17)35	20
	7	Brooks property	Grit mass	7(20)25	31
	9	Henrich property	Katemcy mass	7(20)40	26
	11	Thaxton property	Katemcy mass	7(22)40	26
	12	Hoffman property	Katemcy mass	6(22)45	24
	16	Schweers property	Medium grained	7	33
	17	Sherwood property	Katemcy mass	7	24
	19	Flat Rock	Katemcy mass	7(20)40	22

[a]The name given is that which the property had at the time the sample was collected.

[b]The first number indicates the average grain size of the mesh or matrix minerals; the second number in parentheses indicates the average length of the feldspar phenocrysts; and the third number is the maximum length of feldspar phenocryst measured. Where only one figure is given, the rock is non-porphyritic.

†Distance to Fredericksburg which is no longer on a railroad.

M*=microscopic.

owner, quarry, or topographic feature from which it was collected. For convenience of comparison, the rock mass is given from which the granite was obtained. The grain size of the uniform-grained granites ranges between 1.5 and 10 mm. The porphyritic coarse-grained granites have a very wide range in grain size, and the maximum-sized phenocrysts are in M–4 and have an average length of 26 mm. and a maximum length of 55 mm. The mesh minerals in this granite, however, average only 5 mm. in size; whereas in many, the mesh minerals average 8 mm. in size.

The granites have been divided into three groups, namely, uniform grained, somewhat porphyritic, and distinctly porphyritic, and then arranged in each group according to increase of grain size (Table 14).

extent, the texture of the granites and the color of the matrix minerals. One of these groups (Table 15) may be briefly described as follows: light pink granites, the pink mostly containing some orange. These granites are uniformly coarse grained and somewhat porphyritic. They contain 2 to 8-mm. splotches of femic minerals and milky white splotches of plagioclase. The granites on the basis of the color of the pink feldspar are arranged from light to dark. The first one is much lighter colored than the next one in the series, and it has a very faint amethystine color.

Table 15. Color variation of central Texas light pink granites.

M–7 (light colored)
Bl–11
Bu–13
Ll–30
Ll–36
Bu–6
Bu–12
Bl–15
M–19
Ll–43
Ll–23 (dark colored)

Table 14. Grain size of central Texas pink and red granites.

Uniform grained		Somewhat porphyritic		Distinctly porphyritic	
No.	Size mm.	No.	Size mm.	No.	Size mm.
Ll–31	1.5	Ll–16	3(11)20	L–35	M*(3)6
Ll–62	2	Ll–29	2(12)25	M–5	6(17)35
Ll–33	2	Ll–44	2(13)20	Ll–30	5(17)40
Ll–41	2.5	Ll–12	4(13)20	G–15	7(18)35
M–3	3	Ll–23	4(14)30	Ll–13	7(19)30
Ll–45	3	Ll–63	5(17)30	Bu–9	7(19)35
G–11	5	Bu–6	6(18)30	Ll–28	7(20)30
Ll–32	5	Bu–5	6(19)35	M–19	7(20)40
G–16	6	M–7	7(20)25	M–9	7(20)40
M–16	7	Ll–43	7(21)30	M–11	7(22)40
M–17	7	Ll–36	8(22)40	M–12	6(22)45
Bl–7	7	Ll–14	8(23)35	M–4	5(26)55
Bl–1	7	Bl–15	8(23)40		
Bl–8	8	Bl–11	8(23)40		
Bl–9	10	Bu–13	8(24)40		
		Bu–12	8(26)40		

M* = *microscopic.*

The above grain sizes were obtained mostly by measurements upon polished specimens without the aid of a microscope. Several of the granites have occasional phenocrysts which, seen in the field, are larger than stated in the above table. During the field work the measurement of phenocryst sizes was neglected in general. The above table, however, probably indicates the relative grain sizes rather accurately.

The granites have a wide range in color. It is difficult to describe colors so that they can be visualized. For this reason the granites were arranged in series of color variations taking into account, to a limited

Dark pink granites (Table 16) form another important group in which the pink color contains abundant orange. These granites are mostly coarse grained and porphyritic. The femic mineral areas are subdued by the dark-colored feldspars, and milky plagioclase is very scarce. Two granites which have features in common with both of these groups are Ll–16 and

Ll–12 which may be considered as transitional between the first and second groups. The second group on the basis of the feldspar color is arranged from light-colored to dark-colored granites.

Table 16. Color variation of central Texas dark pink granites.

Ll–13	(light colored)
M–4	
Bu–5	
M–5	
Bu–9	
M–12	
Ll–28	
M–9	
G–15	
Ll–14	
Ll–63	
M–11	(dark colored)

A third important group of granites (Table 17) has a much greater color range, but the pink of the feldspars contains very little orange. These granites are mostly shades of rose and rust. They are uniform-grained, nonporphyritic, fine- and medium-grained granites. They are arranged in ascending order of intensity of color.

Table 17. Color variation of central Texas rose and rust-colored granites.

M–3	(light colored)
Ll–62	
Ll–33	
Ll–41	
Ll–31	
Ll–32	
G–16	
G–11	
M–16	
M–17	(dark colored)

Three unusual, medium-grained granites of Blanco County are salmon-colored. These are Bl–1, Bl–7, and Bl–8.

Ll–44 and Ll–29 are pale pinkish-gray granites which have some characteristics of both the gray and the pink granites. They are fine-grained porphyritic granites which are probably somewhat contaminated by digested country rock.

Three other granites cannot be classified with any of the above series. One of these, Ll–45, is a pale whitish-pink, fine-grained granite; another, Bl–9, is a beautiful, medium- to coarse-grained granite that almost defies description; and the third, Ll–35, is the chocolate-brown, amorphous-appearing llanite which is studded by opalescent quartz crystals and coral-pink feldspars. Both Bl–9 and Ll–35 take an unexcelled polish.

The group of pink granites described has a wide range of colors and textures. They are excellent building, monumental, and ornamental stones with few exceptions. The granites from Bl–11 and Ll–23 contain an objectionable amount of calcite. The granite from M–4 is nonuniform in color and also contains a small amount of calcite. It is noted, however, for its extremely large feldspars. The location of the pink granites is shown in Plate 1 (in pocket).

Description by Localities

Blanco County

LOCALITY BL–1

Location and geology.—A granite mass is located 2 miles north of the hard-surfaced Austin-Fredericksburg highway and 1.4 miles east of Hye. The deposit is mostly on the south bank of Pedernales River and west of the road at McDougal's Crossing. The distance to Fredericksburg is about 25 miles.

The granite outcrops in Pedernales River, but the main mass of stone forms a small rounded hill on the south bank of the river. The exposure is mostly bouldery, and only a small amount of smooth-surfaced rock is outcropping. No quarries have been opened; consequently, it is hard to predict the type of quarry that can be developed. Joints are rather numerous, inclusions were not seen, and pegmatites are scarce.

Megascopic description.—The granite is of an unusual, light salmon-pink color. It is very similar in color to Bl–7 and Bl–8, described later. The predominant mineral is feldspar, quartz is abundant, and the femic minerals are scarce. The texture is medium grained, nonporphyritic. The minerals average about 7 mm. across with an occasional feldspar as much as 15 mm. in length. The quartz averages about 6 mm. across, and the femic mineral clusters average about 2 mm. across. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, microperthite, quartz, and plagioclase. Biotite is common but not abundant. Pleochroic halos are very common in the biotite. Accessory minerals are fluorite, magnetite, and zircon. Alteration products are abundant, among which are chlorite, sericite, limonite, and decomposition products of feldspar. The feldspars are very much clouded. Microcline is much the most abundant feldspar present, and most of it is highly perthitic. A few crystals of plagioclase are present which are only slightly cloudy and which are of an oligoclase composition. The fluorite is mostly closely associated with the biotite. Occasional flakes of biotite have sieve texture with fluorite occupying the openings. A few euhedral fluorite crystals are present in the more perthitic portions of the microcline. Some of the quartz appears to be of an early period of crystallization, and in places stringers of microcline cut entirely through quartz grains. The granite is much altered. It appears to have been subjected to deuteric alteration late in its formation. The sample examined has in addition been affected by weathering.

The granite is a soda-potash granite similar to the next two granites described, Bl–7 and Bl–8. A chemical analysis of Bl–8 suggests that these granites belong to the late differentiates of the Town Mountain granites. They are in fact of a chemical composition similar to aplites, and from their leucocratic nature might very well be termed aplogranites as defined by Bailey and Maufe.[30]

Recommendations.—The granite is of an unusual color, and none of similar color and texture has been found elsewhere in central Texas except in this immediate area. The physical properties and the mineralogical composition are such that the granite is strong and durable. The sample examined was obtained from near the surface, and the feldspar is somewhat decomposed. With depth the feldspar will become fresher, and the strength of the rock will increase. This is a very desirable monumental granite.

[30]Bailey, E. B., and Maufe, H. B., The geology of Ben Nevis and Glen Coe: Mem. Geol. Surv. Scotland, no. 53, p. 158, 1916. "Aplogranites are rocks of granitic structure consisting essentially of alkali felspar and quartz, with subordinate biotite; hornblende is generally absent; muscovite may be present or absent."

LOCALITY BL–7

Location and geology. A granite mass is located approximately 1 mile up Pedernales River to the west from Bl–1, previously described. The total distance by road to Fredericksburg is about 26 miles. The granite outcrops in the river, but the main mass forms a hill to the westward. Inclusions were not seen, and pegmatites are very scarce. The outcrop is bouldery, jointing is abundant, and solid ledges are not well exposed. Cambrian glauconitic limestone dips northward away from the granite mass.

Megascopic description.—The granite is almost identical in color and grain size to Bl–1, described above.

Microscopic description.—The granite is essentially the same microscopically as Bl–1 except for a slightly higher plagioclase content. The plagioclase is sericitized, and many crystals contain abundant small, strongly birefringent scales of the mineral. Fluorite is in sufficiently large crystals to be recognized with the aid of a hand lens. The granite is a soda-potash granite similar to Bl–1.

Recommendations.—The same recommendations are made for this granite as for Bl–1.

LOCALITY BL–8

Location and geology.—A granite mass is located about 1 mile west of Bl–7, previously described. The deposit is reached by a farm road heading north across Pedernales River near the county line and is about 2.5 miles from the highway and a total distance of about 22 miles from Fredericksburg. A map of the granite outcrop is shown in figure 3. The granite mass is an old monadnock, of the pre-Cambrian peneplain, which is surrounded by Cambrian sediments up to the base of the Wilberns formation. The granite stands a few feet above the surrounding glauconitic Cambrian limestones. It outcrops as a mass of weathered boulders with the freshest exposures being in Iron Rock Creek. Inclusions were not seen, and pegmatites are very scarce. Joints are very numerous at the surface.

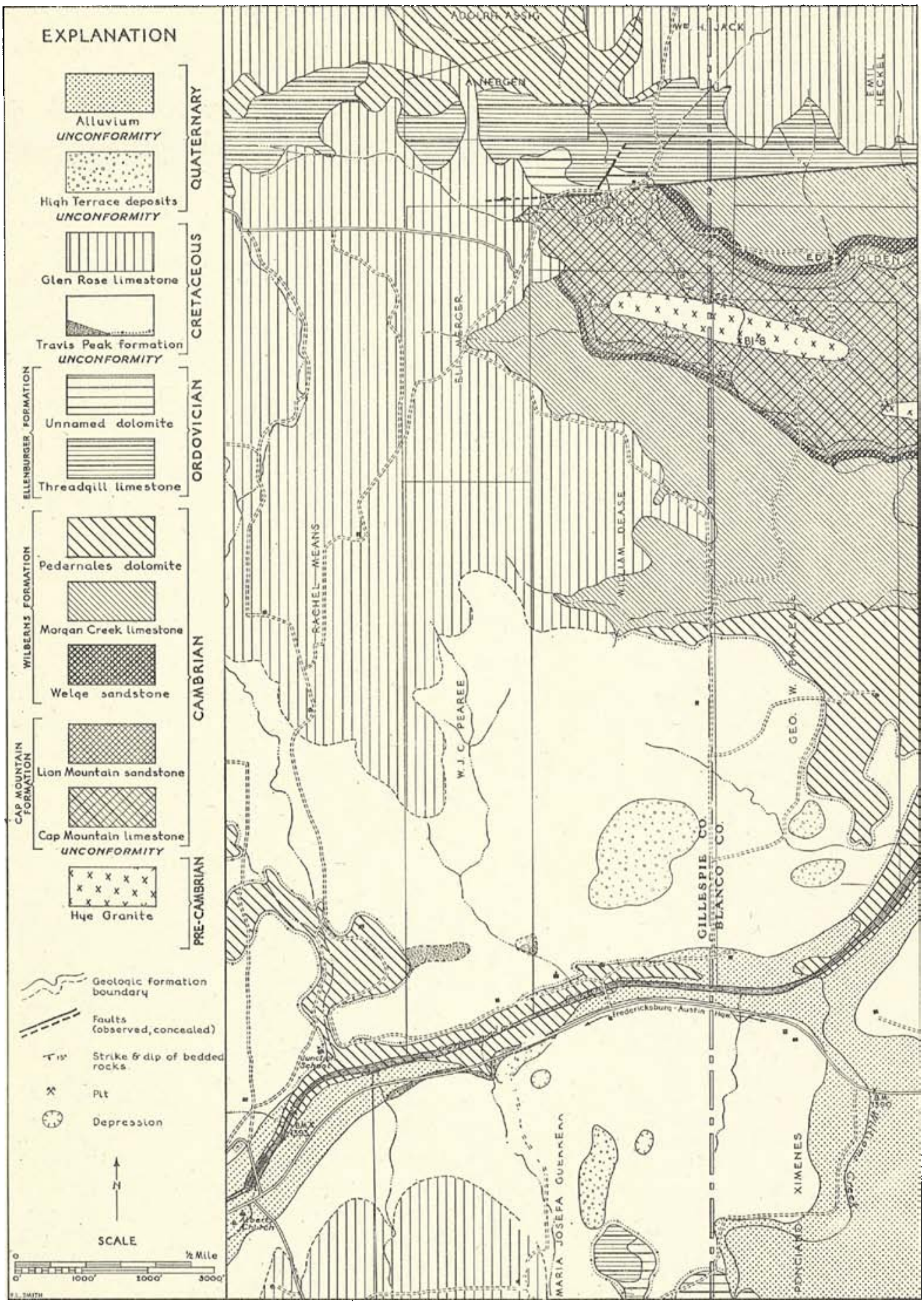

Fig. 3. Geologic map of an area in Texas along Pedernales River at the Blanco-Gillespie County line.

Megascopic description.—The granite has a slightly larger grain size than Bl–1 and Bl–7, already described. A few of the feldspars in the granite have zonal structure, and the quartz has a faint suggestion of opalescence. The color is a slightly lighter salmon-pink; otherwise the granite is very similar to Bl–1 and Bl–7.

Microscopic description.—The granite is essentially the same as Bl–1 and Bl–7. Fluorite crystals up to 3 mm. across and a small amount of rutile are present. The feldspars appear to be slightly less weathered than in the other two granites.

Chemical analysis.—A chemical analysis of the granite and the normative mineral composition as calculated from the analysis are given in Table 18.

Table 18. Iron Rock Creek granite.

Chemical analysis[a]	Per cent
SiO_2	78.87
Al_2O_3	11.20
Fe_2O_3	0.52
FeO	0.72
MgO	0.15
CaO	0.61
Na_2O	3.10
K_2O	4.54
H_2O+	0.12
H_2O-	0.06
CO_2	0.09
TiO_2	0.12
P_2O_5	0.01
MnO	0.02
BaO	0.00
F	0.24
S	0.03
	100.40
Less O	0.11
	100.29

Normative mineral composition	Per cent
Quartz	42.30
Orthoclase	26.69
Albite	26.20
Anorthite	1.67
Corundum	0.61
Hypersthene	1.09
Magnetite	0.70
Ilmenite	0.15
Apatite	0.02
Fluorite	0.55
Calcite	0.20
Pyrite	0.06
Normative plagioclase	$Ab_{91}An_{6}$
Symbol 1.3".(1)2.3.	

[a] Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysts: R. B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

The granite contains an abnormally high quartz content and a very low femic mineral content. Its composition is such that it is an extremely durable stone. Its durability is also attested by its resistance to weathering as indicated by the height at which this granite mass stands above the pre-Cambrian peneplain. The calcite content is a little more than normal for central Texas granites, but this amount is apparently of little consequence. The amount of pyrite contained is low. The chemical analysis shows that this is a very good granite.

LOCALITY BL–9

Location and geology.—A granite mass is located about 7.5 miles by road west of Johnson City and is mostly on the south bank of Pedernales River. The deposit is 5.5 miles by a secondary road from the highway and about 30 miles from the nearest railroad, which is at Marble Falls. It is about 35 miles from Fredericksburg and about 56 miles from Austin.

The south side of the granite mass is bounded by a fault of small throw along which Cap Mountain limestone has been dropped against the granite. Disseminated galena in slightly glauconitic limestone is exposed in some prospect holes along the fault. To the north and to the east glauconitic Cap Mountain limestones rest unconformably upon the granite. The granite is brownish red and contains numerous small inclusions, a few pegmatites, and a few mylonite seams. The granite is somewhat more massive, and joints are wider spaced than in the other three granite masses along Pedernales River.

Megascopic description.—The color of the granite is very unusual, and it is the only one of its kind yet found in central Texas. The color is definitely brownish, tinged with red and yellowish green. Feldspar is the predominant mineral and gives the rock its unusual color. Areas in some of the feldspar are definitely yellowish green, and other areas and lines are reddish brown. Some of the feldspars have an internal pearly to iridescent luster. This luster is confined to feldspars which have slight openings along the cleavage. Quartz is abundant, and some of it is faintly opalescent. Areas of femic minerals are common. The granite is medium to coarse grained, nonporphyritic, and the minerals average about 10 mm. across. The quartz and the femic mineral groups average about 8 mm. across. The granite takes an excellent polish.

Microscopic description.—The granite is composed predominantly of microperthite and quartz with some hornblende and biotite. Plagioclase is extremely rare as individual crystals and where present is associated with the femic mineral areas. It is common, however, in the microperthite as an intergrowth. The amount of intergrown plagioclase is difficult to determine, but many of the crystals appear to be composed of 50 per cent or more plagioclase. Accessory minerals are magnetite, apatite, and zircon. Alteration products are common. Chlorite, having a considerable range in composition, has been produced from the hornblende and biotite. Sericite is limited to a few flakes situated along fracture planes. The microcline of the microperthite is very cloudy, and the perthitically intergrown plagioclase is mostly clear.

Chemical analysis.—A chemical analysis of the granite and the normative mineral composition as calculated from the analysis are given in Table 19.

Table 19. Granite from along Pedernales River.

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	74.10	Quartz	29.16
Al_2O_3	12.75	Orthoclase	30.58
Fe_2O_3	0.83	Albite	33.54
FeO	1.88	Anorthite	1.67
MgO	0.16	Hypersthene	2.91
CaO	0.63	Magnetite	1.16
Na_2O	3.95	Ilmenite	0.46
K_2O	5.20	Apatite	0.07
H_2O+	0.10	Fluorite	0.31
H_2O-	0.04	Calcite	0.32
CO_2	0.14	Pyrite	0.04
TiO_2	0.24		
P_2O_5	0.03	Normative	
MnO	0.05	plagioclase	$Ab_{95}An_5$
BaO	0.04	Symbol 1.4.1.3.	
F	0.12		
S	0.02		
	100.28		
Less O	0.06		
	100.22		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysis: R. B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

The chemical analysis shows that this is a good granite. The calcite content is above normal for the central Texas granites, but apparently this is of little consequence, as attested by the height at which this granite mass stands above the old pre-Cambrian peneplain. The pyrite content is very low. The granite is a soda-potash granite. The chemical analysis suggests that it is a late differentiate of the Town Mountain granites. It may well be termed an aplogranite.

Recommendations.—The color of the granite is unusual, and it is the only one from central Texas having this color. It takes an excellent polish and is a very desirable monumental and ornamental stone. The granite contains rather a large number of inclusions which would increase the cost of producing clear stone. Even though this granite is rather far from the railroad, it should be produced because of its unusual color and its property of taking a high polish.

LOCALITY BL-11

Location and geology.—A granite mass is located about 2 miles southwest of Sandy post office on Grape Creek and is 24 miles by road from the nearest railroad, which is at Marble Falls. Half of the road is unimproved, and the other half is hard surfaced. The granite is 31 miles by road, 8½ miles of which is unimproved, from Fredericksburg.

The granite is coarse grained, pink, and is part of a large granite mass which is mostly covered by Paleozoic sediments. It is exposed at intervals for about 2 miles up Grape Creek from the point at which the sample was taken. The best developed set of joints trends N. 40° W., and a minor set trends N. 40° E. Some inclusions are present; one about 3 by 4 feet in size appears to be quartzite. The granite contains a few pegmatites. Two periods of shearing with crushing are recognized. The crushed rock in the oldest shear zone is completely lithified and adherent to the granite. The zone is about 18 inches wide. A later set of minor shear zones cuts the older one. The mylonite in the later zones breaks free from the enclosing granite. The granite exposures for the most part are low lying and along the creek. One small typical rounded granite knob, however, was seen about 1 mile to the northeast. Large smooth surfaces of granite are present in the creek. With some stripping, favorable quarry sites might be developed away from the creek.

Megascopic description.—The granite is coarse grained and somewhat porphyritic.

It is of a light pink color with the pink containing some orange. The predominant mineral is feldspar, much of which is pink and the rest of which is milky grayish white. Quartz is abundant, and the femic mineral groups are common. The average length of the feldspar phenocrysts is 23 mm. The largest one measured is 40 mm. in length. The quartz areas are irregular and vary considerably in size. Each quartz area is made up of numerous 2 mm.-sized grains. Many of the large feldspars are broken and have veinlets through them. The femic mineral groups, white feldspar and quartz grains, average about 8 mm. across and form a mesh about the pink feldspars. The granite takes a fair polish.

Microscopic description.—The granite is composed predominantly of microcline, quartz, plagioclase, and biotite. Accessory minerals are magnetite, fluorite, apatite, titanite, and zircon. Minerals produced by alteration are chlorite, calcite, sericite, and albite. The feldspars are slightly cloudy. The granite has been subjected to alteration probably of a deuteric type. The quartz has been granulated, and many of the large feldspars broken. New minerals have been formed such as albite, calcite, and sericite. The presence of calcite is detrimental. A thin section of a large microcline crystal reveals a few inclusions of small plagioclase crystals. Quartz present in this crystal appears to have been introduced along minute fractures. The original plagioclase in the granite is oligoclase in composition. One crystal measured contained 80 per cent of the albite molecule. The quartzite-like inclusion is composed predominantly of reticulated quartz, with some microcline, biotite, and plagioclase. The reticulate mineral in the quartz is more abundant at the centers of the quartz grains than it is at the borders.

Recommendations.—The granite contains calcite which limits its usefulness. It has been altered rather extensively, and a few rusty-colored areas have been produced by liberation of limonite during the decomposition of the biotite. The development of a quarry site would necessitate considerable stripping. The presence of shear zones in which the texture and color of the granite are changed will cause excessive waste during quarrying. Unless some better quality granite can be obtained in some of the near-by dome-like masses, this granite area cannot be recommended for building stone.

LOCALITY BL–15

Location and geology.—A granite mass located about 1.5 miles north of Sandy post office near the head of Hickory Creek is about 23 miles from the nearest railroad, which is at Marble Falls. Ten miles of the road is slightly improved and the rest is hard surfaced. Fredericksburg is about 36 miles from the granite mass by road.

The granite is coarse grained, pink, and is one of the surface exposures of a large granite mass which is mostly covered by Paleozoic sediments. The granite is probably from the same mass as Bl–11, previously described. The best exposures of the granite are in Hickory Creek where some outcrops as much as 50 feet across are present. An area to the west of this creek is underlain by granite and is covered by a disintegrated granite soil. A fault trending about NE-SW drops Cambrian sandstone against the granite near the top of a divide to the southwest. The granite contains very few inclusions. Some pegmatites and aplites are present. Some mylonite is present along joints which trend N. 40° W. Another set of less well developed joints trends N. 30° E.

Megascopic description.—The granite is coarse grained, pink, and somewhat porphyritic. The predominant feldspar is pink containing some orange, and the rest is milky white. Quartz and femic mineral areas are plentiful. The pink feldspars average 23 mm. in length, and the largest feldspar measured is about 40 mm. long. The milky feldspar, quartz, and femic mineral groups average about 8 mm. across and form a coarse-grained mesh which surrounds the pink feldspar groups and individuals. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, biotite, and hornblende. Accessory minerals are magnetite, apatite, and zircon. Minerals formed by alteration are chlorite and sericite. The feldspars are flecked by small cloudy areas. Pleochroic halos have formed about zircon crystals included in the biotite. The plagioclase is oligoclase in composition, ranging from Ab_{72} to Ab_{87}. Most of the measurements obtained were near Ab_{82}.

Chemical analysis.—A chemical analysis of the granite and the normative mineral composition as calculated from the analysis are given in Table 20.

Table 20. Granite from north of Sandy post office.

Chemical analysis[a]	Per cent	Normative mineral composition	Per cent
SiO_2	69.52	Quartz	22.74
Al_2O_3	15.44	Orthoclase	32.80
Fe_2O_3	0.27	Albite	28.82
FeO	2.42	Anorthite	8.62
MgO	0.27	Corundum	0.61
CaO	2.08	Hypersthene	4.26
Na_2O	3.43	Magnetite	0.46
K_2O	5.48	Ilmenite	0.61
H_2O+	0.24	Apatite	0.24
H_2O-	0.04	Fluorite	0.07
CO_2	0.17	Calcite	0.39
TiO_2	0.30	Pyrite	0.08
P_2O_5	0.10		
MnO	0.04	Normative plagioclase	$Ab_{77}An_{23}$
BaO	0.12	Symbol 1.4.2.3.	
F	0.04		
S	0.04		
	100.00		
Less O	0.03		
	99.97		

[a] Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysts: R. B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

Calcite and pyrite are higher than normal for the granites of central Texas. The chemical analysis shows that this is the least desirable granite examined. The granite is a soda-potash granite.

Recommendations.—The granite is of attractive appearance but chemically is not very satisfactory. It is not well exposed and is very far from a railroad. Granite of almost identical appearance is available near the railroad in Burnet County; consequently, granite such as this will not be economically produced under present conditions.

Burnet County

LOCALITY BU-5 (GRANITE MOUNTAIN, TEXAS PINK GRANITE COMPANY QUARRY)

Location and geology.—A large rounded dome of granite with a very large quarry on the eastern side is situated 2 miles west of Marble Falls. A railroad was built primarily to this quarry and then extended about 2 more miles into Marble Falls. The quarry was opened in 1882 for the purpose of obtaining stone for the construction of the Texas State Capitol building at Austin.

The large Granite Mountain dome is part of the Granite Mountain granite mass which is many miles across and from which all of the pink granites described from Burnet County, as well as a few of those which are described from Llano County, were obtained. Figure 4 shows

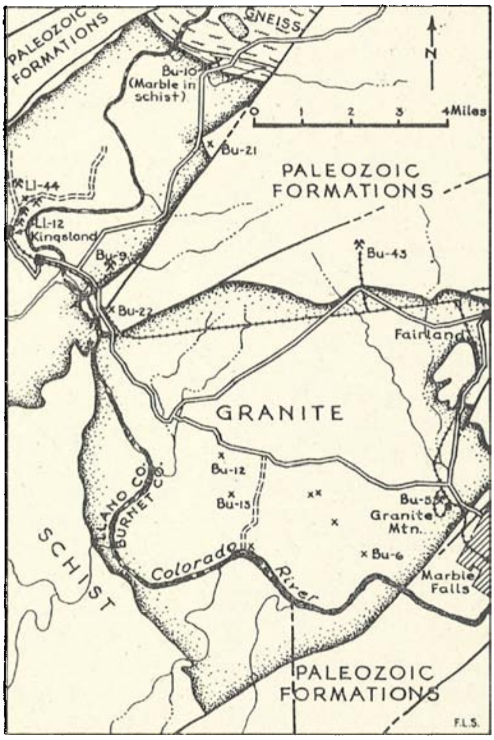

Fig. 4. Geologic map of the Granite Mountain granite mass, adapted from U.S. Geological Survey Llano-Burnet folio.

the approximate area of this large granite mass. To the north and east sediments of Paleozoic age lie upon the granite, and it is unknown how far in these directions it may extend.

This granite dome is relatively free of imperfections. No inclusions were seen, and only a few pegmatites and aplites are present. These mostly strike between N. 30° E. to N. 60° E. and dip between 25° and 60° to the northwest. Joints are widely spaced. The most prominent set strikes N. 15° W. and another strikes N. 70° E. A very small amount of mylonite is present along some of the joints.

The Texas Pink Granite Company started operations in 1893 and up to 1940 shipped between 33½ and 34 million tons of stone from Granite Mountain. The granite has been used widely for dimension stone, jetties, and seawalls.

Several million cubic feet of this granite have been used in New York and may be seen in such buildings as the Whitney Wing and East Wing of the American Museum of Natural History, the Grand Central Station, and many other buildings. The granite has been used in the east building of the Municipal Center, Washington, D. C., the Times Building, Los Angeles; the Northwestern Life Insurance Building, Seattle; the Leif Erickson Memorial, Iceland; numerous tombs and mausoleums in New Orleans; seawalls in Galveston; and jetties at Sabine Pass, Freeport, Galveston, Aransas Pass, and Port Isabel, Texas, and Lake Plaquemine, Louisiana.

The quarry and cutting shed are equipped with two locomotive cranes, one 60-ton and one 40-ton capacity; aerial cableway, 15 tons capacity; four guy derricks, 20 tons capacity; rotary stone saw which will make one cut 5 feet deep or, by turning, can make an 8-foot cut; also can take a block 10 feet wide and any length; an edging machine with carborundum blade; two polishing mills; two surfacing machines; three compressors ranging from 120 to 750 cubic feet capacity; and miscellaneous smaller equipment. The plant can turn out any type of finished stone desired. The largest block shipped so far is 60 tons.

Megascopic description.—The granite is coarse grained and slightly porphyritic. The color is a deep pink containing much orange, and the granite is mottled by dark areas. The chief mineral is pink feldspar, and there is a minor amount of milky feldspar. Quartz is abundant and appears somewhat dark from internal reflections. The femic mineral groups and the quartz grains average about 6 mm. in size. The feldspar phenocrysts average about 19 mm. in length, and the largest one measured is 35 mm. in length. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, microperthite, plagioclase, quartz, biotite, and hornblende. Accessory minerals are scarce and consist mostly of magnetite, titanite, apatite, zircon, and allanite. Minerals formed by alteration are chlorite and sericite. Some of the smaller plagioclase crystals have zonal structure and are altered at the center, resulting in cloudiness and the formation of some sericite. Some of the microcline is only flecked with cloudiness. The plagioclase is mostly oligoclase in composition and contains an average of about 86 per cent of the albite molecule. Most of the plagioclase measured ranges in composition from Ab_{82} to Ab_{90}. One zoned crystal ranges from about Ab_{91} at the center to Ab_{98} at the borders. Some perthitically intergrown plagioclase has a composition of Ab_{90}. The quartz has some undulatory extinction and some mosaic structure detectable when near extinction. Much of the quartz is reticulate and contains long slender needles of rutile and some rhombic and hexagonal plates of ilmenite.

Chemical analysis.—Dr. S. S. Goldich[31] in a recent study of the granites of the region has analysed several of the typical granite masses. His analysis of the granite and the normative mineral composition as

[31]Goldich, S. S., Evolution of the central Texas granites: Jour. Geol., vol. 49, p. 700, 1941.

calculated by him from the chemical analysis are given in Table 21.

Table 21. Granite from Granite Mountain.

Chemical analysis	Per cent	Normative mineral composition	Per cent
SiO_2	73.02	Quartz	29.76
Al_2O_3	13.55	Orthoclase	29.47
Fe_2O_3	0.53	Albite	29.87
FeO	2.12	Anorthite	4.73
MgO	0.16	Corundum	0.61
CaO	1.18	Hypersthene	3.44
Na_2O	3.55	Magnetite	0.70
K_2O	5.02	Ilmenite	0.61
H_2O+	0.18	Apatite	0.20
H_2O-	0.06	Calcite	0.10
CO_2	0.05	Fluorite	0.29
TiO_2	0.31		
P_2O_5	0.08	Normative	
MnO	0.05	plagioclase	$Ab_{87}An_{13}$
BaO	0.05	Symbol I."4.(1)2.3.	
F	0.14		
S	tr.		
	100.05		
Less O	0.06		
	99.99		
Sp. gr. t°/4°	2.657		

The chemical analysis reveals that the granite is exceptionally stable. One of the most objectionable minerals in granite is pyrite because of its tendency to produce brown stains. The element which indicates the amount of pyrite that can be present is sulphur. In the analysis sulphur is present as a trace; consequently, only a trace of pyrite can be present in the granite. Another mineral which is objectionable when present in large amounts is calcite, because of its solubility which tends to cause the stone to disintegrate. The calcite content is very low.

Recommendations.—The Granite Mountain granite is widely used. The most impressive building made of it is the Texas State Capitol building in Austin. It has been widely used on the Texas coast for jetties, breakwaters, and for seawall protection. It is an excellent granite for all the purposes for which a coarse-grained pink granite may be used.

LOCALITY BU–6 (KENNISON ROCK)

Location and geology.—A large dome of pink granite is located 2 miles southwest of Granite Mountain. The distance by road is about 3 miles, all of which is unimproved. The granite is coarse grained and is in a dome that attains a height of about 100 feet above the surrounding area. The granite of Kennison Rock contains more inclusions than do the other granites examined in the Granite Mountain mass. These inclusions are not in parallel arrangement but trend from N. 20° W. to N. 70° E. The predominant direction is N. 40° E., and their dip is nearly vertical. The granite also appears to be slightly finer grained than those to the west. Another very large mass of granite somewhat lower lying is present 100 yards to the west and appears to contain less inclusions. Pegmatites are very scarce. A few mylonite seams occupy some of the joints. Joints are scarce, and enormous areas of smooth rock are present without overburden.

Megascopic description.—The granite is coarse grained, somewhat porphyritic, and light pink. Most of the feldspar is light pink containing some orange, and the rest is milky white. The quartz is clear and appears dark because of internal shadows. The femic mineral areas and the quartz grains are uniformly scattered and average about 6 mm. across. The feldspar crystals average about 18 mm. in length with some as much as 30 mm. long. The femic mineral groups, the white feldspar, and the quartz form a mesh around the pink feldspar. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microperthite, plagioclase, quartz, biotite, and hornblende. Accessory minerals are magnetite, titanite, apatite, and zircon. Minerals formed by alteration are very scarce and consist chiefly of chlorite and sericite. The feldspars are flecked with cloudy areas. The plagioclase is oligoclase in composition and contains an average content of about 85 per cent of the albite molecule. A few of the smaller plagioclase crystals have zonal structure. The quartz has undulatory extinction and mosaic structure detectable when near extinction. Some grains contain long slender needle-like inclusions of a reticulated mineral which is probably rutile. A few rhombic plates of ilmenite are present.

Recommendations.—The granite is in a large mass in a favorable position to quarry. The stone is of good quality but contains inclusions which would cause some waste if clear stone were to be produced. This is an excellent mass from which to produce blocks for jetties and other uses where inclusions are immaterial.

LOCALITY BU-9 (HOOVER QUARRY)

Location and geology.—A granite mass located 1.5 miles east of Kingsland and 0.5 mile northeast of the railroad is coarse grained and free of inclusions. A few pegmatites are present. The outcrop covers about 2 acres and forms a low rounded dome. A quarry established on the south side of the mass was started rather low where some of the surface rock is weathered. The main mass, however, appears to be sound.

Megascopic description.—The granite is porphyritic, coarse grained, and dark pink. Most of the feldspar is dark pink containing considerable orange, and a small amount is milky white. The quartz is clear and appears dark because of internal shadows. The quartz and the femic minerals are mostly associated in elongated areas composed of many grains. Some of these areas are 40 mm. long and 10 to 20 mm. across. The feldspars average about 19 mm. in length, although some are as much as 35 mm. in length. The average size of the rest of the minerals is about 7 mm. across. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, microperthite, quartz, plagioclase, and biotite. Accessory minerals are very scarce and consist of magnetite, apatite, zircon, and fluorite. Alteration products are scarce and consist of chlorite and sericite. The feldspars are mostly only flecked by cloudy areas. The plagioclase is in part zonal in structure with the centers more cloudy than the borders. The plagioclase is oligoclase in composition. The quartz has undulatory extinction. One reticulated quartz grain was seen in thin section containing long slender rutile needles and ilmenite plates.

Recommendations.—The granite is of good grade and can be used for building or for massive stone in jetties and other construction of similar nature. The granite is very similar to that being produced at Granite Mountain except that it has a slightly deeper color.

LOCALITY BU-12 (HOG MOUNTAIN)

Location and geology.—A granite dome is located just south of the Marble Falls-Kingsland road 5 miles west of Granite Mountain. The nearest railroad is 2.5 miles to the north. Hog Mountain is a typical rounded dome of granite and stands about 50 feet above the surrounding rather flat country. The granite is coarse grained and is free of aplites, pegmatites, and inclusions. The main sets of joints trend N. 50° W. and N. 70° E. Other masses of low-lying granite outcrop near Hog Mountain.

Megascopic description.—The granite is coarse grained, somewhat porphyritic, and light pink. Much of the feldspar is light pink containing some orange, and the rest is milky white. The quartz is clear and appears slightly dark but not as much so as in many of the granites, since it is mostly associated with white feldspar. The quartz, femic minerals, and white feldspar are associated, forming a network which enmeshes pink feldspar groups or individuals. The femic mineral areas average about 5 mm. across, the quartz areas about 7 mm. across, and the white feldspar about 10 mm. across. The average grain size of this group of minerals is about 8 mm. in diameter. The pink feldspars average about 26 mm. in length with several as much as 40 mm. in length. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, microperthite, plagioclase, quartz, hornblende, and biotite. Accessory minerals are magnetite, titanite, apatite, and zircon. Minerals formed by alteration are scarce and are chlorite and sericite. The microcline is flecked with cloudiness, and much of the plagioclase is clear. The plagioclase is oligoclase in composition. Micropegmatitic intergrowth is abundant. The quartz has undulatory extinction and mosaic structure detectable when near extinction. Several of the large microcline crystals enclose plagioclase crystals. A small amount of reticulated quartz is present in which long slender needles of rutile are present. Some ilmenite plates are present in the plagioclase.

Recommendations.—The granite is of excellent grade and is suitable for all purposes for which a coarse-grained granite can be used. The color and clearness of the minerals make this a very decorative and desirable granite.

LOCALITY BU–13 (ANDERSON ROCK)

Location and geology.—A granite mass is located about 1 mile south and a little east of Hog Mountain (Bu–12), previously described. It is about 5 miles by road from Granite Mountain. The granite is coarse grained and is in the shape of a large rounded dome standing well above the surrounding country. The granite is free of joints and inclusions. Pegmatites are present but are widely spaced. The surface of the granite mass is smooth, and fresh granite can be quarried within a few inches of the surface.

Megascopic description.—The granite is coarse grained, somewhat porphyritic, and light pink. Much of the feldspar is light pink containing some orange, and the rest is milky white. The quartz is clear and appears slightly dark because of interior shadows. The white feldspar surrounds and is mostly situated in contact with the pink feldspar. The femic minerals have a tendency to be segregated in the mesh intersections formed by the white feldspar, quartz, and femic mineral groups, which in turn enclose the pink feldspar groups and individuals. The mesh minerals average about 8 mm. across. The pink feldspars average about 24 mm. in length, and the largest feldspar measured is 40 mm. in length. The granite takes a good polish.

Microscopic description.—The granite is in every respect similar to the granite just described (Bu–12). The edge of one quartz grain is slightly reticulated, containing a small amount of rutile.

Recommendations.—The same recommendations are made for this granite as for Bu–12.

MISCELLANEOUS LOCALITIES

Many granite knobs are located in the area between the Marble Falls-Kingsland road and Colorado River. Some of the more prominent of these have been indicated in figure 4. All of these knobs are composed of granite almost identical to that described from Bu–5, Bu–6, Bu–12, and Bu–13. About 1.3 miles south of Bu–13 much granite is exposed in Colorado River for a distance of more than a mile. The knob of granite (fig. 4) 1 mile northwest of Bu–6 is crossed by a power line. On the south side of this mass a very large sun-lift has developed. The rock involved is about 25 by 100 feet in area and 2 feet thick. It has broken near the middle and arched upward, leaving a space of about 2 feet beneath the arch.

These knobs were not sampled since the rock is entirely similar to that already described. The supply of easily obtainable stone in this area is so large that it is practically inexhaustible.

Gillespie County

LOCALITY G–11 (BEAR MOUNTAIN, NAGEL BROTHERS QUARRY)

Location and geology.—The Bear Mountain granite mass is located about 4.5 miles north of Fredericksburg by road which is graded but otherwise unimproved. The granite mass is entirely surrounded by Cretaceous sediments. A map of Bear Mountain, made by using aerial photographs as a base, is reproduced as figure 5. Bear Mountain has an area of about 82 acres. Balanced Rock, a large rounded boulder, situated near the top of this mass, is supported by such small pedestals that it is quite a novelty to sightseers who are willing to scramble up the steep sides of this boulder-strewn granite mass. The entire surface of the hill is covered by large boulders, and none of the smooth granite surfaces so common on the coarse-grained granites are present. Nagel Brothers quarry is situated at the south end of the mass. Some of the more prominent joint directions are N. 40° E., 88° NW.; N. 58° W., 54° SW.; N. 58° W., 86° NE.; N.–S., 24° E.; N. 82° E., vertical; N. 30° E., vertical; and N. 20° W., 58° NE. A north-south joint dipping 24° to the east, which is exposed in a previously worked portion of the quarry, feathers out up dip into a series of *en échelon* fractures trending N. 50° W. and dipping 88° to the northeast. Slickensides are present on some of the joint surfaces. A very small number of black inclusions are present. Pegmatites and aplites are scarce. One aplite trends N. 60° W. and dips 46° to the southwest. The aplites are identical in color to that of the granite but are much finer grained. In November 1938 a rather large face had been developed upon a block of granite which is free of joints.

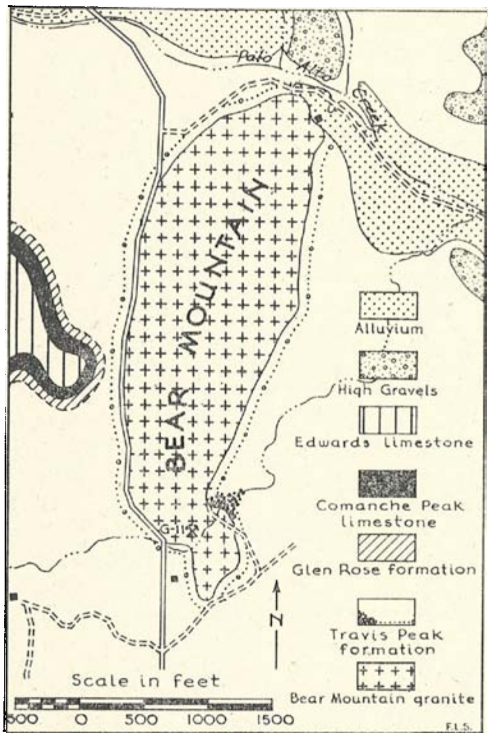

Fig. 5. Geologic map of the Bear Mountain granite mass, 3.5 miles north of Fredericksburg, Gillespie County, Texas.

Megascopic description.—The granite is of a uniform medium to fine grain and rust-red in color. The feldspar is predominantly rust-red, and a very small amount is pinkish white. The quartz is mostly finely granular and has somewhat of a cracked-ice appearance. A few clear nongranular quartz grains are present which are very dark from internal shadows. Biotite is very scarce, and 2 mm.-sized flakes are spaced at an average distance of nearly an inch apart. The quartz is present as elongated areas about 10 mm. in length. The mineral grains average about 5 mm. in size. The feldspar crystals are so nearly of the same color that their size is not readily apparent. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of plagioclase, microcline, quartz, and biotite. Accessory minerals are magnetite, fluorite, and apatite. Alteration products consist of much sericite and flecks of cloudiness in the feldspars. A very small amount of chlorite is present. Much of the cloudy material is seen by reflected light to be tinged by red. The quartz grains of the granite have been crushed, and the feldspar and biotite crystals are distorted. The fractured quartz grains, however, are now perfectly healed as is shown by the high crushing strength of the rock. The plagioclase is albite-oligoclase in composition and contains an average of about 90 per cent of the albite molecule.

Chemical analysis.—Dr. S. S. Goldich[32] in a study of the granites of central Texas analysed several of the typical granite masses. His analysis of the Bear Mountain granite and his calculation of the normative mineral composition are given in Table 22.

Table 22. Bear Mountain granite.

Chemical analysis	Per cent	Normative mineral composition	Per cent
SiO_2	76.77	Quartz	36.12
Al_2O_3	13.22	Orthoclase	26.69
Fe_2O_3	0.32	Albite	31.96
FeO	0.36	Anorthite	2.22
MgO	0.16	Corundum	1.22
CaO	0.66	Hypersthene	0.80
Na_2O	3.80	Magnetite	0.46
K_2O	4.47	Ilmenite	0.15
H_2O+	0.13	Apatite	0.03
H_2O-	0.02	Calcite	0.30
CO_2	0.12	Fluorite	0.13
TiO_2	0.08		
P_2O_5	0.02	Normative plagioclase	$Ab_{91}An_9$
MnO	0.05	Symbol I.(3)4.1″.3.	
BaO	tr.		
F	0.06		
S	tr.		
	100.24		
Less O	0.03		
	100.21		
Sp. gr. t°/4°	2.632		

[32] Goldich, S. S., *op. cit.*, p. 700.

The chemical analysis reveals that this is an exceptionally good granite. Just a trace of sulphur is present which indicates that only a trace of pyrite can be present. Calcite is a little more abundant than normal but is so distributed that it will not cause the stone to disintegrate.

The granite is a soda-potash granite. The chemical analysis suggests that the granite belongs to the late differentiates of the Town Mountain granites. It might well be called an aplogranite from its similarity in chemical composition to aplites.

Recommendations.—The granite is extremely handsome and is excellent for building, monumental, and ornamental stone. The granite is much jointed, and considerable waste occurs during quarrying. The contrast between hammered and polished surfaces is very marked. Only one other granite of somewhat similar color (Ll–32) has been found in central Texas.

LOCALITY G–15

Location and geology.—A rounded dome of granite is located about 5 miles west and a little south of Enchanted Rock and is about the southwesternmost of the series of granite knobs which are exposed around the eastern and southern sides of the large Enchanted Rock granite mass. Fredericksburg is about 20 miles distant by road, half of which is paved and the rest of which is graded but otherwise unimproved. A map of the southern part of the Enchanted Rock granite mass, figure 6, shows a more detailed location of sample G–15. The map also shows areas of exposed granite surfaces in this portion of the Enchanted Rock granite mass.

The outcrop has an area of about 250 by 350 feet and stands about 30 feet above the general level of the vicinity. The granite weathers with the large phenocrysts of feldspar standing in relief. The biotite and feldspars of the granite are roughly aligned vertically in a N. 70° W. direction. The most prominent joint direction trends N. 36° E., and another poorly defined set trends N. 63° W. A few other poorly defined joint directions are present. The granite is practically free of inclusions and pegmatite veins.

Megascopic description.—The granite is porphyritic, coarse grained and dark pink. The feldspar is predominantly dark pink, containing considerable orange, and a small amount of feldspar is present that is greenish gray. The quartz is clear and only slightly dark from internal reflections. The quartz areas are elongated, and some are as much as 40 mm. long and 10 mm. across. The femic mineral areas average about 4 mm. across. The pink feldspars average about 18 mm. in length, and the largest one measured is 35 mm. long. The feldspars are somewhat enmeshed by the other minerals which average about 7 mm. across. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, hornblende, and biotite. The accessory minerals are magnetite, titanite, apatite, zircon, rutile, and fluorite. Some pleochroic halos are present in the biotite. Micropegmatite is common. Minerals formed by alteration are chlorite and sericite. The microcline is mostly clear and the plagioclase is somewhat clouded. Zonal plagioclases are mostly cloudy at the center and clear at the border. The plagioclase is oligoclase in composition. The quartz has some undulatory extinction and some mosaic structure detectable when near extinction.

Recommendations.—The granite is excellent for buildings and monuments but, at present, is rather inaccessible to a railroad. This granite dome and many others in the area are excellent quarry sites.

LOCALITY G–16

Location and geology.—A low-lying mass of granite is located about 2 miles north of Willow City and is 17 miles by road from Fredericksburg. Twelve miles of this road is hard surfaced, and the rest is graded but otherwise unimproved. A map of the area, figure 7, shows three areas of outcrop of the granite. The configuration of these areas suggests that they are a portion of a large granite mass now mostly covered by Paleozoic and Cretaceous sedimentary rocks. Inliers of granite near Willow City, 0.7 mile west of Eckert, 1.5 miles southwest of Eckert, and 4 miles

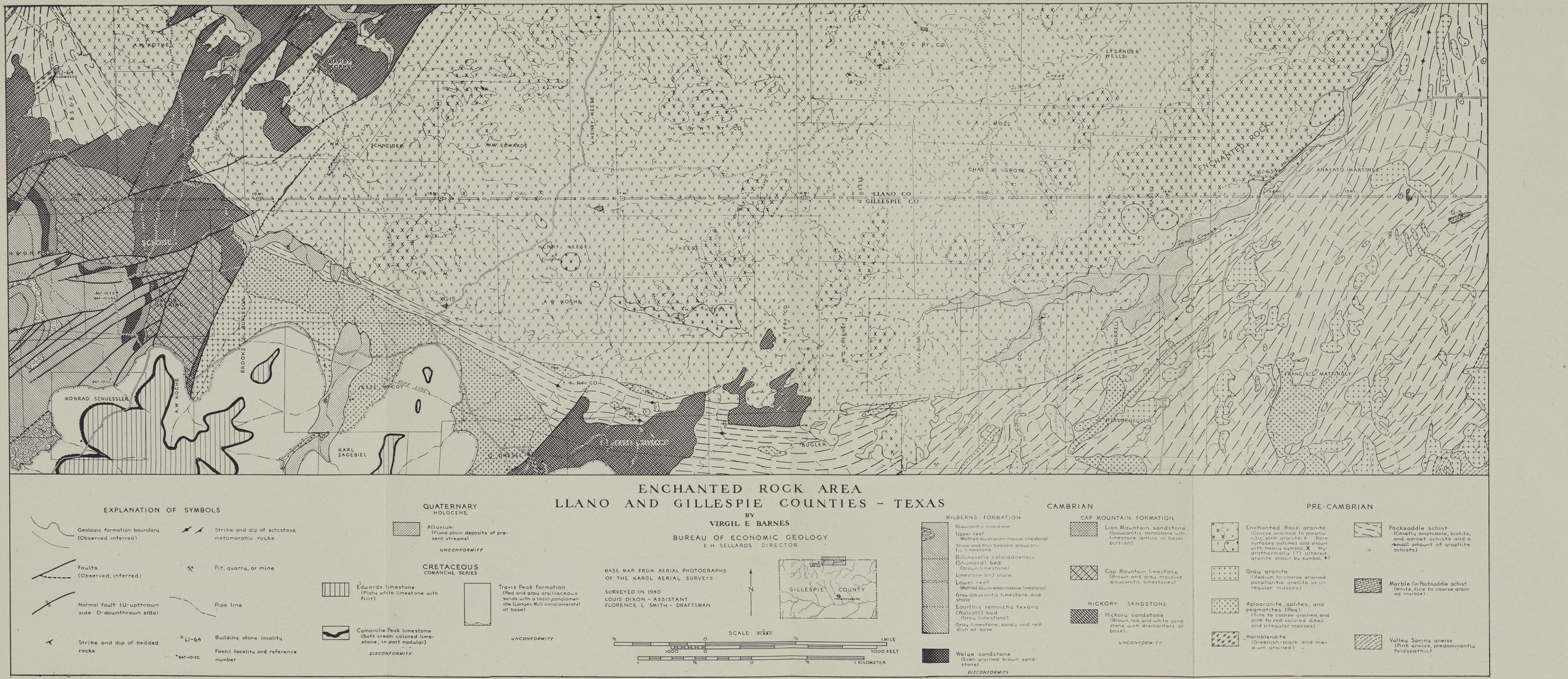

Fig. 6. Geologic map of the Enchanted Rock area, Gillespie and Llano counties, Texas.

east and east-southeast of Willow City may belong to the same granite mass. A portion of the Legion Creek granite mass is shown in the northern part of the map. The two granites are separated in part by an east-west trending dike of younger fine-grained red aplitic granite which contains inclusions of the coarse-grained granite. The Legion Creek granite mass probably connects with the mass to the south at a rather shallow depth. Sandstone of Cambrian age overlies the granite in part. Cretaceous conglomerates in other places directly overlie the granite. The granite has been exposed to weathering prior to the deposition of the Cambrian sandstone, prior to the deposition of the Cretaceous conglomerates, and again during the present weathering cycle. The granite is consequently deeply weathered, and the sample obtained is not entirely fresh. To the east 1.5 miles, however, erosion during the present cycle has been more rapid, and unweathered granite has been uncovered. Inclusions and pegmatites are extremely scarce. The main direction of jointing is N. 30° E. A few narrow veins of mylonite follow some of the joints.

Megascopic description.—The granite is medium grained and of a rose-pink color. The feldspars are rose-pink and form a mesh in which abundant quartz and a

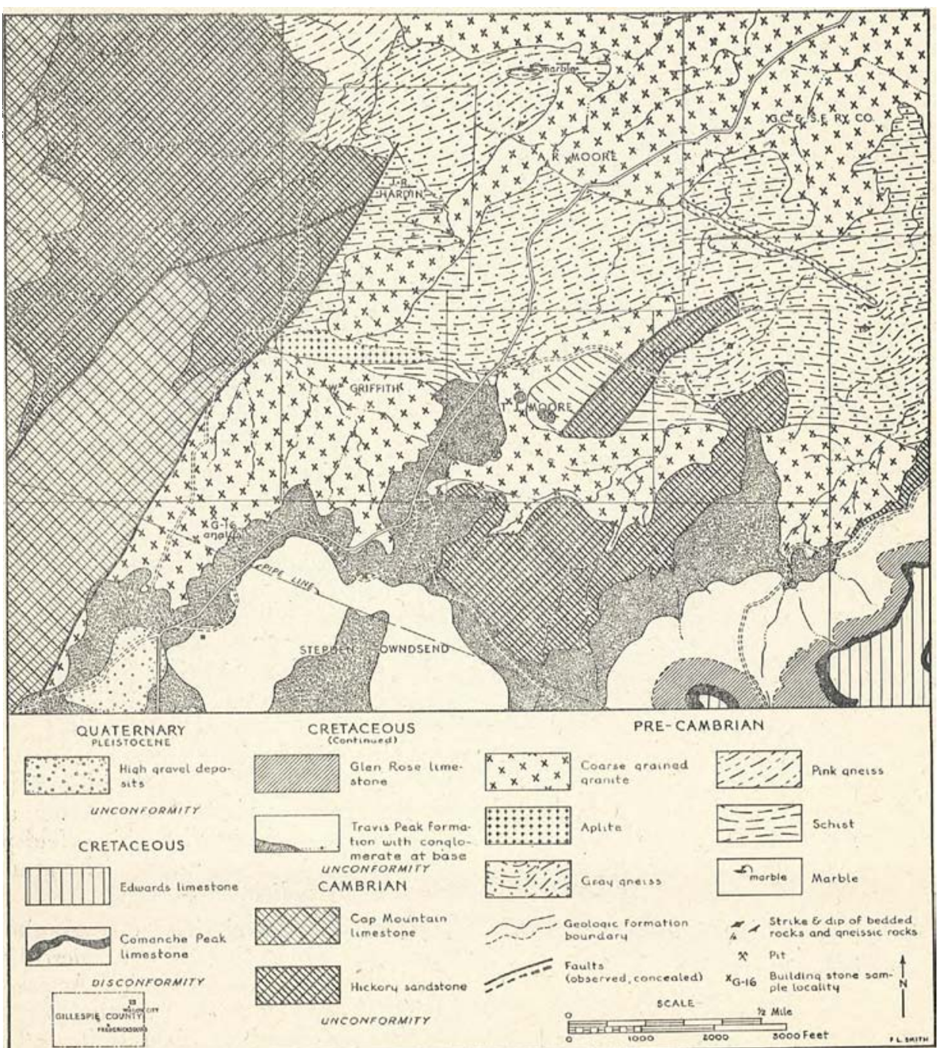

Fig. 7. Geologic map of an area northeast of Willow City, Gillespie County, Texas.

small amount of the femic minerals are enclosed. The quartz is clear and varies from light to dark depending upon internal shadows and associated femic minerals. The quartz areas, some of which are elongated, average 5 mm. across. The femic minerals are mostly 2 mm. or less across and the feldspar probably averages about 8 mm. in length. The average grain size of the rock as a whole is about 6 mm. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are scarce and consist of magnetite, fluorite, zircon, and apatite. Minerals formed by alteration are chlorite and sericite. The microcline is slightly flecked by cloudiness, and the plagioclase is mostly cloudy. The amount of cloudiness is rather great in the plagioclase, and much of it is tinged with pink. The plagioclase is oligoclase in composition. The quartz has very little undulatory extinction. A small amount of reticulated quartz is present containing long slender needles of rutile and plates of ilmenite.

Chemical analysis.—A chemical analysis of the granite and the normative mineral composition as calculated from the analysis are given in Table 23.

Table 23. Granite from north of Willow City.

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	76.75	Quartz	36.54
Al_2O_3	12.42	Orthoclase	31.14
Fe_2O_3	0.27	Albite	26.72
FeO	0.86	Anorthite	2.22
MgO	0.18	Corundum	0.71
CaO	0.71	Hypersthene	1.46
Na_2O	3.13	Magnetite	0.46
K_2O	5.26	Ilmenite	0.15
H_2O+	0.15	Apatite	0.02
H_2O-	0.04	Fluorite	0.31
CO_2	0.13	Calcite	0.30
TiO_2	0.12	Pyrite	0.06
P_2O_5	0.01		
MnO	0.02	Normative	
BaO	0.00	plagioclase	$Ab_{92}An_8$
F	0.12	Symbol I.3(4).1″.3.	
S	0.03		
	100.20		
Less O	0.06		
	100.14		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysts: R. B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations) Fluorine determination by Willard and Winter method.

The chemical analysis of the granite indicates an excessive calcite content; otherwise, it is a very good granite. The granite is a soda-potash granite.

Recommendations.—The granite is an excellent monumental and building stone. The minerals are very fresh appearing, and the granite takes an excellent polish. The granite is rather low lying and is not as favorably located for quarrying as many of the rounded domes found elsewhere. The outcrop previously mentioned, 1.5 miles to the east could be developed into an excellent quarry site.

Llano County

LOCALITY LL–12 (PETRICK GRANITE COMPANY QUARRY)

Location and geology.—An abandoned granite quarry, located along the south side of the railroad 1 mile northwest of Kingsland, is about 200 by 300 feet in area, is shallow, and is now nearly full of water. The surface is composed of weathered granite necessitating considerable stripping to obtain solid stone. It is more coarsely crystalline than is the granite exposed in quarries to the north. Inclusions and pegmatites are present. A small quarry 0.3 mile to the northwest has been opened by the same company. In this quarry inclusions are numerous, pegmatites are present, and mylonite occupies some of the joints.

Megascopic description.—The granite is medium grained, somewhat porphyritic, and pink. Much of the feldspar is an intermediate pink containing some orange, and the rest of the feldspar is grayish white. The pink feldspars average about 13 mm. in length and the longest ones are about 20 mm. They are enmeshed by a medium-grained mixture of quartz, grayish feldspar, and femic minerals. The femic minerals average about 2 mm. across, and the quartz and grayish-white feldspar average about 4 mm. across. The granite takes a fair polish.

Megascopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are magnetite, apatite, zircon, titanite, and fluorite. Minerals formed by alteration are chlorite and sericite. The microcline and some of the plagioclase are clear with only occasional flecks of cloudiness. A few of the zonal plagioclase crystals are rather highly altered. The quartz has undulatory extinction and a slight mosaic structure detectable when near extinction. The plagioclase is oligoclase in composition. Some reticulated quartz in the granite contains long slender needles of rutile and a few rhombs of ilmenite.

Recommendations.—The granite is a good monumental and building stone which has been used extensively for jetties. It is of a pleasing and rather unusual color. The quarry is in a flat area in which the granite is deeply weathered, and the opening of a quarry would, for this reason, be expensive since much weathered stone must be stripped.

LOCALITY LL–13

Location and geology.—A granite mass, located in a rather inaccessible portion of southwestern Llano County, is about 25 miles from Llano by road, much of which is unimproved, and about 27 miles from Fredericksburg by way of Loyal Valley, 4 miles to the west. The highway from Loyal Valley to Fredericksburg is hard surfaced.

The secondary road leading to the granite outcrop crosses Marshall Creek on a smooth surface of granite. The main outcrop, however, is a rounded granite knob about one-fourth of a mile downstream from the road crossing. At the creek crossing, the plane-flow structure, indicated by the alignment of numerous black inclusions, is vertical and trends N. 5° E. Many of the inclusions have large porphyroblasts of feldspar in them. An aplite and some quartz gash veins trend N. 60° W. and dip 45° to the southwest. Mylonites occupy some of the joints. Poorly defined joints trend N. 50° E. and N. 80° W. Numerous rounded domes of granite 10 to 15 acres in extent are present in this area. The southernmost dome of the group is free of inclusions and joints and has very few aplites in it.

Megascopic description.—The granite is coarse grained, porphyritic, and dark pink. The feldspars are predominantly dark pink containing considerable orange, and a few are milky white. The granite has a definite mineral alignment in which the feldspars are oriented mostly in one direction and are separated by highly elongated areas of quartz. The quartz is so clear that in many crystals the underlying minerals can be seen. The quartz areas are as much as 10 cm. long and average about 5 mm. in width. The femic minerals are mostly associated with the quartz and average about 3 mm. across. The average grain size for the minerals as a whole is about 7 mm. The pink feldspar averages 19 mm. in length, and the longest ones are about 30 mm. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, microperthite, quartz, plagioclase, and biotite. Accessory minerals are magnetite, fluorite, apatite, zircon, and titanite. Chlorite and sericite are rather common. The microcline is mostly clear, and the plagioclase is cloudy. Some of the plagioclase crystals are zoned with the centers more cloudy than the borders. Considerable micropegmatite is present. Pleochroic halos are common in the biotite. The quartz has undulatory extinction and some mosaic structure detectable when near extinction. The plagioclase is oligoclase in composition.

Recommendations.—The granite is of a very good color, takes an excellent polish, and is a good monumental and building stone. Large masses are present upon which quarry sites can be located. The granite is a long distance from a railroad.

LOCALITY LL–14 (KINGSLAND GRANITE COMPANY (PETRICK) QUARRY)

Location and geology.—A quarry is located on a low-lying rounded dome of granite about 2 miles west of Buchanan Dam at the intersection of the Llano and lake shore highways. The southern part of the quarry is free of inclusions, aplites, and pegmatites. At the extreme northern end of the quarry one inclusion is about 5 by 10 feet in size. Pegmatites and aplites are common at this end of the quarry. Goldich[33] describes the pegmatites and aplites as follows:

> Pegmatite, aplite, and vein quartz appear to be related genetically to the granite and are well exposed in the quarry. The pegmatite consists of large crystals of microcline, some of which meas-

[33] Goldich, S. S., *op. cit.*, pp. 703, 708–709.

ure a foot or more across, intergrown with quartz. Biotite, fluorite, gadolinite, garnet, molybdenite, and a few other minerals in lesser amounts occur in the pegmatite. . . . Aplite and pegmatite dikes are numerous in the granites of the Llano region. The aplite commonly grades into pegmatite, and this relationship can be seen in a dike in Petrick's quarry. The dike is about 15 feet wide. It contains schlieren of granite, but its relationships to the granite are sharp and transgressive. A small amount of biotite is uniformly distributed in small flakes throughout the gray to pink aplite. The texture is typically sugary, and in thin section the subhedral, mutually sutured grains are of the same order of magnitude. Albite near oligoclase, microcline, and quartz are the essential minerals, and biotite and fluorite, which has every appearance of being primary, are the only accessories. There is, however, a small amount of calcite and chlorite. . . . Near the center of the dike the aplite grades into a zone of pegmatite which swells to a thickness of several feet. Large equidimensional crystals of potassic feldspar, quartz, and books of biotite up to 8 inches in diameter compose the pegmatite.

The main joint direction trends N. 80° E. and dips 80° to the north. The granite is very uniform, and the size of block that can be produced is limited only by the weight that can be handled by the quarry machinery.

Megascopic description.—The granite is coarse grained, somewhat porphyritic, and dark pink. The feldspars are mostly dark pink containing considerable orange. A few of the pink feldspar phenocryts are mottled and zoned by pearly gray feldspar. The granite has in part an orbicular structure. The femic minerals are grouped in irregularly shaped and widely varying sized splotches which are up to 20 mm. in size. The quartz is very clear and is only slightly darkened by internal shadows. The quartz grains average about 6 mm. in size. The feldspars are somewhat euhedral and average about 23 mm. in length with some as much as 35 mm. in length. The average size of the rest of the minerals is about 8 mm. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, quartz, plagioclase, biotite, and hornblende. Accessory minerals are magnetite, titanite, apatite, fluorite, and zircon. Minerals formed by alteration are chlorite and sericite. The microcline is mostly clear or only slightly flecked by cloudiness. The plagioclase is mostly cloudy and is oligoclase in composition. Some of the microcline feldspars are orbicular, having centers of plagioclase, quartz, and biotite. In some the central material is microcline surrounded by plagioclase containing biotite, the whole of which is in turn enclosed by microcline. Some micropegmatite is present. The quartz has some undulatory extinction and a small amount of mosaic structure detectable when near extinction.

Chemical analyses.—Dr. S. S. Goldich (p. 700) analysed the granite and an aplite dike from Petrick's quarry. F. A. Gonyer[31] analysed a sample from the same quarry as well as two other granites from the same granite mass. These analyses are given in Table 24.

Table 24. Chemical analyses of granites from Lone Grove granite mass.

	(A)	(B)	(C)	(D)	(E)
	Per cent				
SiO_2	71.85	72.20	68.36	74.58	76.65
Al_2O_3	13.69	13.30	14.82	12.99	13.31
Fe_2O_3	0.57	0.47	1.26	0.67	0.10
FeO	2.74	3.28	2.99	1.24	0.50
MgO	0.25	0.34	0.69	0.44	0.05
CaO	1.56	1.10	1.52	0.51	0.56
Na_2O	3.47	3.58	3.88	3.78	4.65
K_2O	5.08	4.95	4.98	4.91	4.15
H_2O+	0.23	0.26	0.35	0.42	0.10
H_2O-	0.05	0.09	0.09	0.06	0.04
CO_2	0.08	none	none	none	0.03
TiO_2	0.44	0.42	0.48	0.18	0.04
P_2O_5	0.14	0.05	0.13	0.02	tr.
MnO	0.05	0.07	0.03	0.02	0.02
BaO	0.09	0.06	0.09	0.04	0.01
F	0.12	n.d.	n.d.	n.d.	0.13
S	0.01	none	0.09	none	tr.
Cl	n.d.	none	0.02	none	n.d.
SrO	n.d.	none	none	none	n.d.
	100.42	100.17	99.78	99.86	100.34
Less O	0.05				0.05
	100.37				100.29
Sp.gr. t°/4°	2.671				2.617

(A) Coarse-grained granite, Petrick quarry, Llano County, Texas. Analyst, S. S. Goldich.

(B) Coarse-grained granite, Petrick quarry, Llano County, Texas. Analyst, F. A. Gonyer.

(C) Porphyritic coarse-grained granite, road cut 0.65 mile south of second bridge south of intersection of State highways No. 29 (old) and No. 261, Llano County, Texas. Analyst, F. A. Gonyer.

(D) Medium-grained granite, road cut 0.45 mile south of intersection of State highways No. 29 (old) and No. 261, Llano County, Texas. Analyst, F. A. Gonyer.

(E) Aplite, Petrick quarry, Llano County, Texas. Analyst, B. D. Brundidge.

[31]Keppel, David, Concentric patterns in the granites of the Llano-Burnet region, Texas: Bull. Geol. Soc. Amer., vol. 51, p. 977, 1940. Analyses by F. A. Gonyer.

The normative mineral composition of these granites are given in Table 25.

Table 25. Normative mineral composition of granites from Lone Grove granite mass.

	(A)	(B)	(C)	(D)	(E)
			Per cent		
Quartz	27.24	27.07	21.23	31.49	32.87
Orthoclase	30.02	29.25	29.47	29.01	24.46
Albite	29.34	30.33	32.80	31.96	38.77
Anorthite	6.67	5.56	6.67	2.50	2.11
Corundum	----	----	0.55	0.49	0.41
Hypersthene	4.56	6.05	5.19	2.42	0.83
Magnetite	0.84	0.70	1.86	0.93	0.23
Ilmenite	0.84	0.76	0.91	0.46	0.08
Apatite	0.34	0.12	0.34	0.05	tr.
Calcite	0.20	none	none	none	0.07
Fluorite	0.23	----	----	----	0.27
Pyrite	0.02	none	0.18	none	tr.

	Normative plagioclase	Symbol
(A)	$Ab_{82}An_{18}$	I″.4.″2.3.
(B)	$Ab_{85}An_{15}$	I.4.2.3.
(C)	$Ab_{83}An_{17}$	I.4.2.3.
(D)	$Ab_{93}An_{7}$	I.4.1.3.
(E)	$Ab_{95}An_{5}$	I.″4.1″.3(4).

The chemical analyses of samples (A), (B), and (E) reveal that the Petrick granite is an exceptionally good granite. In two analyses sulphur was not detected, and in the third only 0.01 per cent was found. Pyrite, therefore, is practically absent. Calcite is absent except for an exceedingly small amount in the aplite of the Petrick quarry. The granite from which analysis (C) was obtained has not been visited in the field, and consequently the character of the granite is unknown to this writer. The amount of pyrite indicated by analysis (C) is rather high and might limit the usefulness of the stone.

Recommendations.—The granite is a very beautiful stone which is not entirely uniform in texture and color. The variation is caused by the irregular distribution of femic minerals. Some areas in which the concentration of femic minerals is great are dark in color, while other areas which are deficient in femic minerals are light in color. The lack of uniformity in color enhances the beauty of the stone especially on large surfaces. The Brown Building at Lavaca and Eighth streets, Austin, Texas, is faced in part by polished stone from this quarry. The granite is excellent for any use for which a coarse-grained pink granite is desirable.

LOCALITY LL-16

Location and geology.—A granite dome is located 5.5 miles northeast from Lone Grove and is just southeast of the Tow road. It is 8 miles from the nearest point on the railroad which is 2.5 miles south of Lone Grove. The granite is exposed as an elliptical dome about 200 by 300 feet in size, which stands about 8 feet above the surrounding flat terrain. Outcropping granite may be traced down a drainage to the southeast. A 7-inch pegmatite-aplite crosses the outcrop in a direction N. 60° E. Joints are very scarce. One set trends N. 45° E., and another set trends N. 65° W. On a portion of the outcrop recently uncovered, the surface of the granite is etched by long shallow grooves trending N. 80° W. The granite is free of inclusions, and the northwestern part of the outcrop is practically free of pegmatites. Pegmatites are more numerous to the southeast.

Another outcrop of coarse-grained porphyritic granite about 10 acres in size is exposed one-half mile to the northeast along the north side of the Tow road. Joints are widely spaced, inclusions are absent, and pegmatites are scarce. Mylonite is present along some of the joints but in general is scarce. The surface stone is somewhat disintegrated, and a satisfactory sample was not obtained.

Megascopic description.—The granite is medium grained, somewhat porphyritic, and pink. The feldspars are mostly of an intermediate pink containing some orange, and a few are milky white. Quartz is abundant in 3 mm.-sized grains. Femic minerals are common and average about 2 mm. in size. The feldspars average about 11 mm. in length. A very small number of euhedral feldspars, 20 mm. in length, are present. The minerals are all very evenly distributed. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, biotite, hornblende, and augite. Accessory minerals are magnetite, titanite, fluorite, apatite, and zircon. In addition to the usual pleochroic halos seen about zircon, some halos are present which show a ringed structure and are much larger. These halos have probably formed about some other radioactive mineral. Sericite and chlorite are present. Much of the quartz is reticulated and contains abundant plates of ilmenite and abundant long slender needles of rutile concentrated in the central part of the quartz grains. The rutile is present either as long needles or as a disconnected series of aligned dots and dashes. Other series of dots or slightly elongated dots commonly present appear to be some mineral other than rutile. In some of these the mineral is elongated in a direction transverse to the alignment. The plagioclase is oligoclase in composition.

Recommendations.—The granite is a good building and monumental stone. The mass exposed is not very large, yet a good quarry could be developed upon it. Away from the outcrop small gullies expose smooth granite surfaces at shallow depths, and it is likely that with a small amount of stripping, quarry sites could be developed over a large area.

LOCALITY LL–23 (TOWN MOUNTAIN)

Location and geology.—Town Mountain which is composed of granite is located north of Llano and about 2 miles by road from the railroad. Several small quarries have been opened on the eastern and northern sides of the peak. The rock is rather dark-colored and contains pink feldspar. Some pegmatites are present, and inclusions are very abundant, many of which are of Packsaddle schist. At the eastern end of this peak, the pitch of the linear flow structure is at an angle of 24° in a direction S. 45° E. The plane-flow structure strikes N. 65° E. The granite is sound and is of value where uniformity of composition and color is not required.

Megascopic description.—The granite is coarse grained, somewhat porphyritic, and light pink. Two types of feldspars are present which are about equal in amount. One is light pink containing some orange, and the other is milky white. The granite has a definite mineral alignment with the feldspars and femic minerals oriented in one direction. The pink feldspar averages about 14 mm. in length with some as much as 30 mm. in length. The pink feldspars are surrounded by a mesh which is an intimate mixture of white feldspar, quartz, and femic minerals averaging about 4 mm. in grain size. The granite takes a poor polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Hornblende is present but is very scarce. Accessory minerals are abundant and consist of magnetite, titanite, apatite, and zircon. Minerals produced by alteration are calcite, sericite, and chlorite. The calcite is mostly associated with the biotite areas and is rather plentiful. Sericite is very abundant and in places forms small veinlets crossing feldspars and in some places even crosses quartz grains. Micropegmatite is common. The quartz has undulatory extinction and marked mosaic structure detectable when near extinction. Pleochroic halos are present but are not abundant. The plagioclase is oligoclase in composition. The plagioclase of the microperthite has an estimated composition of $Ab_{98}An_2$ and a refractive index very near that of the microcline.

Chemical analysis.—Dr. S. S. Goldich[35] in a study of the granites of the region made an analysis of the Town Mountain granite (Table 26) which is considered as the type for Stenzel's Town Mountain granites. The normative mineral composition of the granite as calculated by Goldich from the chemical analysis is also given in Table 26.

Table 26. Town Mountain granite.

Chemical analysis	Per cent	Normative mineral composition	Per cent
SiO_2	68.15	Quartz	22.14
Al_2O_3	15.15	Orthoclase	30.02
Fe_2O_3	0.62	Albite	28.82
FeO	3.29	Anorthite	8.34
MgO	0.77	Corundum	1.02
CaO	2.03	Hypersthene	6.39
Na_2O	3.44	Magnetite	0.93
K_2O	5.06	Ilmenite	1.37
H_2O+	0.38	Apatite	0.54
H_2O-	0.03	Calcite	0.20
CO_2	0.08		
TiO_2	0.67	Normative plagioclase	$Ab_{79}An_{21}$
P_2O_5	0.23	Symbol I'.4.2.3.	
MnO	0.08		
BaO	0.11		
S	tr.		
	100.09		
Sp. gr. t°/4°	2.691		

[35] Goldich, S. S., *op. cit.*, p. 700.

The chemical analysis shows that this is a good granite. Pyrite can be present only as a trace. Calcite is present in minor amounts and is mostly associated with the biotite. By solution of the calcite the biotite might eventually be loosened and fall out, thus leaving a pitted surface. There is scarcely enough calcite present, however, to cause a general disintegration of the stone.

Recommendations.—The granite is not satisfactory for building and monumental uses. Inclusions are rather numerous, and the granite does not take a good polish. The granite is of value for constructing jetties, seawalls, and similar structures where appearance does not matter.

LOCALITY LL–28

Location and geology.—A granite mass is located about 10 miles west of Oxford by unimproved road and is a total distance of about 21 miles from Llano. From Oxford to Llano, the highway is hard surfaced. This is part of the Enchanted Rock granite mass and is about the northernmost well-defined granite knob of the series of knobs which outline the eastern and southern part of the mass. The outcrop is somewhat more rugged than the outcrop of most of the granite knobs of the area. Joints are not well developed, and the chief direction appears to be about N. 50° E. Inclusions are absent, and pegmatites are scarce. The plane-flow structure strikes about N. 20° W. and is vertical.

Megascopic description.—The granite is coarse grained, porphyritic, and dark pink. The feldspars are dark pink containing considerable orange and average about 20 mm. in length. The largest feldspars are about 30 mm. in length. These feldspars are surrounded by a more or less continuous mesh of clear quartz and femic minerals. The quartz grains average about 7 mm. in diameter and are arranged mostly in elongated areas. The femic mineral clusters are rarely over 5 mm. across, and many are much less. The femic minerals are rather scarce and fairly evenly distributed in the mesh areas. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are magnetite, apatite, fluorite, zircon, titanite, allanite, augite, and hornblende. Pleochroic halos are common in the biotite. The minerals formed by alteration are sericite and chlorite. One crystal of titanite seen in thin section has mostly altered to calcite and leucoxene. The feldspars are largely cloudy with some of the plagioclase crystals being clear. The quartz has some undulatory extinction and some mosaic structure detectable when near extinction. The plagioclase is oligoclase in composition.

Recommendations.—The granite has a fresh appearance and takes a good polish. There is an enormous amount of granite in a favorable position for quarrying but it is far from a railroad and under present conditions can scarcely compete with granites of similar quality which are along railroads.

LOCALITY LL–29

Location and geology.—A granite mass is located about 21 miles southwest of Llano, 19.5 miles of the road being graded, the rest unimproved. The granite is fine grained and pink with a grayish cast. Some phenocrysts of feldspar up to 2 inches in length are scattered through it. Joints are numerous especially in the sheeted granite which is above the general ground level. Some exposures at ground level are much less jointed. Inclusions are absent, and pegmatites are very scarce. Mylonite seams occupy a few of the joints.

Megascopic description.—The granite is somewhat porphyritic, light pink, and has a peppered appearance. The feldspars are mostly light pink, and a few are milky white. The phenocrysts are not abundant and range up to 25 mm. in length. Their average length is 12 mm. The rest of the pink feldspar, the white feldspar, quartz, and femic minerals average about 2 mm. in size and are evenly distributed between the phenocrysts of pink feldspar. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are magnetite, titanite, apatite, zircon, and allanite. Pleochroic halos are common in some of the biotite flakes. Minerals formed by alteration are chlorite and sericite. The microcline is mostly clear, and much of the plagioclase is cloudy. The quartz has scarcely any undulatory extinction. The plagioclase is oligoclase in composition.

Recommendations.—The granite is sound and is of rather an unusual pinkish-gray color. It could be used for building and monumental stone but is too far from the railroad to be used for jetties and similar purposes.

LOCALITY LL–30

Location and geology.—A granite mass is located about 22 miles southwest of Llano, 19.5 miles of the road being graded, the rest unimproved. It is located along House Mountain Branch. The granite contains numerous large phenocrysts of feldspar up to 3 inches in length. Several inclusions contain feldspar porphyroblasts, and several pegmatites are present. Mylonite occupies some of the joints which trend N. 30° W. and N. 30° E. One vertical 2-foot pegmatite trending N. 10° W. contains a mylonite zone in the center. Another vertical pegmatite 7 feet thick trends N. 60° W. and crosses the creek near the outcrop. Much of the pegmatite is a graphic intergrowth of feldspar and quartz. A prominent quartz vein south of the main outcrop trends N. 45° E. The flow structure of the granite is vertical and trends N. 70° E. There are numerous low-lying, rounded, dome-like granite outcrops in this area which range up to 5 acres in extent.

A quarter of a mile west of House Mountain Branch and in one of its tributaries a pronounced vertical shear zone trending N. 50° E. contains parallel mylonite seams. The granite to the southeast of the zone contains numerous inclusions, aligned with their longer axes dipping eastward at an angle of about 5 to 10 degrees. The granite has larger feldspar phenocrysts in it than does the granite to the northeast. The feldspars in the latter granite remain in relief upon weathered surfaces.

Megascopic description.—The granite is coarse grained, porphyritic, and light pink. The large feldspars are of a light pink color containing some orange. They average 17 mm. in length, and the largest ones are 40 mm. long. They are rather widely scattered in a 5 mm.-grained, evenly distributed matrix of white feldspar, clear quartz, and femic minerals. The quartz has a brownish cast, mostly from internal reflections. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of quartz, microcline, plagioclase, and biotite. Accessory minerals are rather abundant and consist of titanite, magnetite, apatite, and zircon. An occasional pleochroic halo has formed around zircon included in biotite. The minerals formed by alteration are chlorite and sericite. Alteration of the biotite is rather pronounced with some of the books composed of alternate zones of brown and green biotite. The final product of alteration is chlorite. Some sericite has formed from the feldspars. The zoned plagioclase is somewhat cloudy, and the rest of it is mostly clear. The microcline is uniformly but sparsely cloudy.

The plagioclase is oligoclase in composition, is mostly without zonal structure, and is chiefly finely albite twinned. Titanite crystals are well developed. The estimated mineral composition in the mesh is quartz 33, microcline 32, plagioclase 26, biotite 8, and titanite 1 per cent. The large microcline phenocrysts are not included in the estimate. No deleterious minerals were found. Micropegmatite is rather scarce. The quartz has little undulatory extinction.

Chemical analysis.—A chemical analysis of the granite and the normative mineral composition as calculated from the analysis are given in Table 27.

The pyrite content is above average for that of the central Texas granites. Calcite is extremely low. The chemical analysis indicates that this is a good granite. It is a soda-potash granite.

Recommendations.—The granite is unusual with pink phenocrysts widely spaced in a mesh of gray minerals. The minerals are fresh and clear, and the granite takes an excellent polish. There is a large amount of this granite, and it is of value for monumental and building stone.

Table 27. Granite from along House Mountain Branch.

Chemical analysis[a]	Per cent	Normative mineral composition	Per cent
SiO_2	69.56	Quartz	23.46
Al_2O_3	14.74	Orthoclase	27.80
Fe_2O_3	0.88	Albite	31.44
FeO	2.34	Anorthite	9.45
MgO	0.75	Hypersthene	4.67
CaO	2.21	Magnetite	1.39
Na_2O	3.73	Ilmenite	0.91
K_2O	4.66	Apatite	0.35
H_2O+	0.26	Fluorite	0.47
H_2O-	0.04	Calcite	0.02
CO_2	0.01	Pyrite	0.08
TiO_2	0.46		
P_2O_5	0.15	Normative	
MnO	0.07	plagioclase	$Ab_{77}An_{23}$
BaO	0.08	Symbol I″.4.2.3.	
F	0.24		
S	0.04		
	100.22		
Less O	0.12		
	100.10		

[a]Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysts: R. B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); C. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

LOCALITY LL–31

Location and geology.—A fine-grained granite mass is located about 6.5 miles southwest of Llano along a small creek about 1.5 miles south of the Llano-Sixmile road. Five miles of the road is graded, and the rest is unimproved. Mr. Parkinson reports that: "The granite is highly jointed at the surface. It is almost free of inclusions and pegmatites. The deposit is rather large, but the amount of good stone is limited."

Megascopic description.—The granite is fine grained and light rust-colored. The feldspars range from a deep to a light rust. The minerals average about 1.5 mm. in size and are uniformly distributed. Feldspar is the most abundant mineral, quartz is abundant, and only about 3 per cent of femic minerals is present. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are magnetite, apatite, and allanite. Minerals formed by alteration are sericite and chlorite. The microcline is mostly clear, and the plagioclase is mostly cloudy. The quartz has some undulatory extinction and some mosaic structure detectable when near extinction. The estimated mineral composition is microcline 49, plagioclase 27, quartz 21, and biotite 3 per cent. The average grain size is about 1.5 mm. The plagioclase is oligoclase in composition.

Recommendations.—The mineral composition and the size and interlocking character of the grains are such that the granite should be very strong and durable. It is an excellent monumental stone but is probably limited in amount.

LOCALITY LL–32 (BALDWIN QUARRY)

Location and geology.—A granite mass is located about 9.5 miles southwest of Llano and about 1.5 miles south of the Llano-Cherry Spring road. Eight miles of the road is graded, and the rest is unimproved. Two quarries were opened in the granite during 1940. The sample used for this report was taken from the Baldwin quarry, which is the westernmost of the two openings. The granite is unweathered practically to the surface. The second quarry, which is operated by Texas Quarries, is located along a hillside in a jointed area. The granite is altered along the joints to the depth of the quarry which at the time it was visited was more than 20 feet deep. The depth of weathering normal to the joints at the 20-foot depth was about the same as at the surface which indicates that weathering may continue much deeper.[36] The surface of the granite is very rough and boulder strewn. Inclusions are absent, and only a few quartz veins and some mylonite zones were seen. The main joint directions are N. 50° E. and N. 35° W. Several other joint directions are present, which complicate the quarrying of the granite. Along some of the joints a thin film of pyrite and quartz is present. No pyrite, however, was seen within the granite.

Megascopic description.—The granite is medium grained and red. The feldspars are mostly rose-colored, and a few are pinkish white. Quartz is not very plentiful and is present as sharply bounded

[36]In July, 1941 a representative of the company informed the writer that the quarry had reached a depth of 50 feet and that weathering still persisted along the joints. The quarry has since been abandoned.

clear grains. Extremely thin biotite flakes about 4 mm. long are present. The grain size averages about 5 mm., and the minerals are fairly evenly distributed except for the sharply bounded quartz grains. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, and quartz with a small amount of biotite. In the thin sections examined the accessory minerals are very scarce. Magnetite, apatite, and zircon were recognized. Micropegmatite is very abundant, and most of the microcline crystals contain quartz in amounts ranging up to 50 per cent. The quartz has undulatory extinction and some mosaic structure detectable when near extinction. Some sericite and a very small amount of chlorite are present. A few crystals of plagioclase are quite cloudy, and others are clear. The microcline is either clear or flecked by small areas of cloudiness. The plagioclase is oligoclase in composition. The estimated mineral composition is microcline 40, plagioclase 33, quartz 26, and biotite 0.4 per cent. The microscopic character and the chemical analysis suggest that the granite is a late differentiate of the Town Mountain granites. The chemical composition is similar to that of an aplite, and the granite might very well be termed an aplogranite.

Chemical analysis.—A chemical analysis of the granite obtained from fresh stone in the Texas Quarries opening and the normative mineral composition of the granite as calculated from the analysis are given in Table 28.

The chemical analysis shows that this is an exceptionally good granite. It is a soda-potash granite.

Recommendations.—The granite is sound and is of value as a building and monumental stone. The amount of weathering along joints is objectionable in portions of the mass. The granite at the western end of the mass is not weathered. Its unusual color has much to recommend it and also places it in direct competition with imported red granites. Once a market is established, the stone should continue to be widely used. A large mass of the granite is present—sufficient to sustain several quarries.

Table 28. Texas Quarries red granite.

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	75.70	Quartz	32.34
Al_2O_3	13.69	Orthoclase	35.58
Fe_2O_3	0.42	Albite	27.77
FeO	0.34	Anorthite	2.50
MgO	0.14	Corundum	0.82
CaO	0.58	Hypersthene	0.30
Na_2O	3.27	Magnetite	0.70
K_2O	5.96	Ilmenite	0.15
H_2O+	0.07	Apatite	0.02
H_2O-	0.04	Fluorite	0.07
CO_2	tr.	Calcite	tr.
TiO_2	0.07	Pyrite	0.04
P_2O_5	0.01		
MnO	0.02	Normative plagioclase	$Ab_{92}An_8$
BaO	0.01	Symbol I.4.1″.3.	
F	0.02		
S	0.02		
	100.36		
Less O	0.02		
	100.34		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysts: R. B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

LOCALITY LL-33

Location and geology.—A granite mass is located about 7.5 miles southwest of Llano and about 0.5 mile south of the Cherry Spring road. All except the last half mile of the road is graded. The granite is fine grained and is of an unusual red color. The main mass of the granite extends for several hundred feet and is about 100 feet wide. Inclusions were not seen upon the surface, but at the western end of the outcrop some rock has been blasted revealing inclusions of schist and gneiss. The granite is much jointed, and the joints are highly irregular in trend. Pegmatites are scarce. The outcrop stands about 10 feet above the general hillside slope.

Megascopic description.—The granite is fine grained and of a dusty rose color. Dusty rose-colored feldspar is the most abundant mineral, clear quartz is abundant, and the femic minerals are rather scarce. These minerals are uniformly distributed as 2 mm.-sized grains. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are very scarce. Magnetite and zircon were recognized. Sericite and chlorite are present as alteration products. The microcline is mostly clear with occasional flecks of cloudiness. The zonal plagioclase is mostly cloudy at the center and clear or only faintly cloudy at the border. Some of the non-zoned plagioclase crystals are clear. The plagioclase is oligoclase in composition. The quartz has much undulatory extinction and much mosaic structure detectable when near extinction. The estimated mineral composition is microcline 41, plagioclase 27, quartz 31, and biotite 1 per cent.

Recommendations.—The granite is an excellent monumental stone, but the size of the mass is small, and at the surface the granite is much jointed. Large masses of very similar granite are described under Ll–41, Ll–31, and Ll–62, where satisfactory quarries can be established.

LOCALITY LL–35

Location and geology.—A quartz porphyry (llanite) dike is located just north of the Llano-Lone Grove road at a distance of about 3.5 miles from the railroad at Llano. It extends as a dike, or a series of dikes, for a distance of 9 miles northward and then swings sharply to the southwest for a distance of 4 miles, crossing the Llano-San Saba highway on the southeastern slope of Baby Head Mountain.

Quartz porphyry is probably the latest intrusive in the region. The quartz phenocrysts of the quartz porphyry are opalescent. It has been named llanite from the county in which it has been found and locally is called "opaline granite." The dike trends N. 10° W. and is about 10 feet thick at the place where the sample was obtained. It extends about 3 feet above the general ground surface and is marked by a linear pile of small, rounded boulders, not unlike the ruins of an old wall. The size of block which can be obtained at this locality is insufficient for most uses. Several miles to the north thicker dikes of quartz porphyry would yield sufficiently large blocks for most uses.

A quarry in opaline granite is located west of Baby Head and about one-fourth mile west of the Llano-San Saba highway. The quarry is in a thickened portion of an opaline granite dike which at this point is less jointed than at most localities visited. Boulders up to 10 feet in size top the outcrop, and blocks of at least that size can be obtained in the quarry. It is free of pegmatites, aplites, quartz seams, inclusions, and other blemishes. Joints are numerous and trend in many directions. The opaline granite is fresh and unaltered to within a fraction of an inch of the surface, and much good stone could even be obtained from boulders. The outcrop forms a steep southeast-facing scarp and is a desirable quarry site. Much good stone has been quarried and piled alongside the quarry in blocks 3 to 5 feet long. The waste pile also contains much good small stone that can be used. This is the most desirable deposit of opaline granite seen, and there is no logical reason apparent why this premium stone should not be available on the market.

Physical tests.—Iddings[37] gives the following data which were determined in the laboratory of The University of Texas Mineral Survey: "Specific gravity, 2.64; corrected, 2.67. One cubic foot of the rock absorbs 9.47 ounces of water. Crushing strength 15,300 pounds per square inch of surface." The above absorption is about 0.36 per cent. The microscopic and megascopic appearance of the opaline granite indicated that the above crushing strength is too low. This property was redetermined, using present-day specification, and the average crushing strength was found to be 37,800 pounds per square inch.

Megascopic description.—The opaline granite has a dense chocolate-brown groundmass surrounding abundant rust-flecked feldspar phenocrysts averaging about 4 mm. in size. Hexagonal phenocrysts of bluish opalescent quartz averaging 3 mm. in size are also abundant. This combination of bluish opalescent quartz, rust-flecked feldspar, and dense groundmass produces a very unusual and attractive rock. It takes an excellent polish, showing little of the accentuation of grain boundaries which is so common in coarse-grained granites.

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[37]Iddings, J. P., Quartz-feldspar-porphyry (graniphyro liparose-alaskose) from Llano, Texas: Jour. Geol., vol. 12, pp. 225–231, 1904.

Iddings (p. 225) has carefully described the llanite as follows:

The material submitted . . . is a gray porphyry with abundant phenocrysts of red feldspar and blue quartz, the matrix or groundmass being aphanitic to phanerocrystalline. It appears to have a crystalline texture, but the individual grains are not distinctly visible without a microscope. The rock is therefore mottled red and gray with light blue spots of opalescent quartz.

The phenocrysts vary in size, the largest feldspars being 10 mm. in diameter, the largest quartzes 5 mm. The quartzes exhibit a beautiful blue color, which is light sky-blue in the central part of the crystal and dark at the margin. The crystals are not all colored to the same degree; some are lighter than others. The color does not change perceptibly with a change in the angle of incidence, or in the position of observation, except that in certain positions there is a brilliant light blue luster. The feldspars are rather uniformly colored light Indian-red, the larger crystals being mottled with gray.

The proportion of phenocrysts and groundmass estimated from the surface of the specimen and from three thin sections is:

Phenocrysts	quartz	10.7
	feldspar	26.5
Groundmass		62.8
		100.0

Microscopic description.—The microscopic description of the llanite as given by Iddings (pp. 225–227) is as follows:

Under the microscope the groundmass is seen to be holocrystalline and microcrystalline, and is composed of feldspar and quartz in nearly equal proportions, together with a small amount of brownish-green mica, and still less fluorite, magnetite, apatite, and zircon. The proportions in which these occur was determined by microscopical measurement to be approximately, in 62.8 per cent of groundmass:

		Total
Quartz,	23.9	34.6
Feldspar,	29.2	55.7
Biotite,	8.6	8.6
Fluorite,	1.0	1.0
Apatite,	0.13	0.13
	62.83	100.03

The fabric of the groundmass is uniformly heterogeneous, being a mixture of automorphic granular and micrographic. It consists of anhedrons of quartz, very free from inclusions, except some minute gas cavities, with similarly shaped anhedrons of microcline slightly clouded with alteration products, besides anhedrons of twinned albite with an approach to automorphism. These anhedrons vary in size from 0.1 to 0.01 mm. in diameter. Throughout the whole are scattered at short intervals granular clusters of graphic intergrowth of quartz and feldspar. The crystallization of the graphic parts was almost contemporaneous with that of the anhedrons, as these are developed in continuous orientation with the graphic clusters.

The mica is xenomorphic in great part, and is in about the same sized anhedrons as the quartz and feldspar. It appears to have been almost contemporaneous in crystallization with these minerals. Its color is green to brownish-green.

Fluorite occurs in irregularly shaped anhedrons, xenomorphic in form. It is colorless in thin sections, exhibits distinct cleavage, and is characterized by its low refraction and isotropic behavior. It is quite uniformly scattered through the groundmass.

Apatite occurs in colorless microscopic prisms. Magnetite and zircon both occur in anhedrons in such small quantities that they were not measured. They appear to constitute a small fraction of 1 per cent of the rock.

A careful study of the feldspars in the groundmass showed that microcline and albite are present in nearly equal proportions, and that they form separate and distinct crystals not perthitically intergrown.

The feldspar phenocrysts are microcline, with extremely minute and regular multiple twinning in two directions. The delicacy of the twinning suggests a possible soda content in the potash feldspar approaching soda microcline. There is also a perthitic inclusion of albite in irregularly shaped shreds, and also a slight clouding due to alteration, which is probably kaolin with hydrous oxide of iron which gives color to the feldspar.

The quartz phenocrysts contain multitudes of minute inclusions, rather evenly distributed through each crystal, except for a margin of nearly pure quartz in some cases. The inclusions are of two kinds, generally intermingled: one consists of extremely thin, colorless prisms, sometimes passing into lines of minute grains, like broken prisms; the other kind is in equally thin tabular crystals with six sides and trigonal shapes, and a light brown color. The colorless prisms have higher refraction than quartz, but the double refraction is not recognizable. They resemble apatite rather than rutile, having lower refraction than rutile and not being so long as rutile needles often are. The width of these prisms varies from 0.000800 mm. to much less; that is, it is mostly a fraction of a wave-length of light. The brownish tabular crystals are equally thin, and range in diameter from 0.004 mm. to much less. Studied by incident sunlight, they exhibit metallic reflections of a bluish-white and also of other colors. They have the crystal form and color of ilmenite.

These inclusions lie at all angles within the quartz crystals, but there appear to be sets of parallel directions intersecting at various angles, so that in some positions many tabular microlites reflect light in one direction. The same is true of the colorless needles. They lie in parallel lines crossing at various angles, whose orientation with respect to the inclosing quartz does not appear to be definite.

The sky-blue opalescent color of the quartz phenocrysts is undoubtedly due to reflection of blue light-waves from the minute colorless prisms, whose width is a fraction of the length of light-waves. It is similar to the blue color of the sky. It is probable, however, that there is also blue light produced by interference of the light reflected from both sides of the minute tabular crystals, whose thickness is also of the order of a fraction of a light wave-length; so that both kinds of phenomena occur within these quartzes.

In addition to the minerals mentioned in the above description muscovite, sericite, and chlorite were seen in the specimen examined by the present writer. The muscovite is present as flakes of the same average size as that of the other groundmass minerals. The sericite is present as small irregular flakes and is an alteration product of feldspar. The chlorite is an alteration product of the biotite. The quartz is practically without undulatory extinction.

Chemical analyses.—Three chemicaal analyses have been made of opaline granite from the H. C. Harned land near Llano. These are analyses I and II, quoted from Iddings (p. 228), in Table 29, which also includes a recent analysis (IV) by Goldich.[38]

Table 29. Chemical analyses of opaline granite.

	I	II	III	IV
			Per cent	
SiO_2	74.9	75.90	74.52	75.20
Al_2O_3	11.1	12.07	11.58	12.27
Fe_2O_3	1.6	1.01	0.69	0.63
FeO	1.5	1.45	2.61	1.89
MgO		0.22	none	0.27
CaO	0.2	0.65	0.82	0.81
Na_2O	8.5	3.08	3.40	3.05
K_2O	tr.	5.32	5.46	5.00
H_2O+ H_2O-	0.3	0.41 0.06	0.36	0.32 0.02
CO_2		none		0.10
TiO_2	0.5	0.38	0.29	0.35
P_2O_5		0.15	0.05	0.06
MnO	1.9	n.d.	0.02	0.06
BaO		n.d.		0.04
F		n.d.	0.49	0.25
S		n.d.		0.01
	100.4	100.70	100.29	100.33
Less O			0.21	0.11
			100.08	100.22
Sp. gr. t°/4°				2.650

I. S. H. Worrell, analyst. (This analysis is inferior.)
II. H. S. Washington, analyst.
III. J. P. Iddings, calculated from microscopic measurements.
IV. S. S. Goldich, analyst.

[38]Goldich, S. S., *op. cit.*, p. 700.

Iddings calculated the chemical composition from a microscopic determination of the amount of the various minerals present, making an assumption that the biotite had a composition similar to that found in the soda granite of Cape Ann, Massachusetts. The calculation was made before a chemical analysis was available and is given as analysis III in Table 29. This shows that a rather accurate estimate of the chemical composition can be obtained by a petrographic examination.

The normative mineral composition calculated by Washington,[39] the modal mineral composition determined by Iddings, and the normative mineral composition calculated by Goldich are given in Table 30.

Table 30. Normative and modal mineral compositions of opaline granite.

	Washington Norm	Iddings Mode	Goldich Norm
		Per cent	
Quartz	35.76	34.6	35.70
Orthoclase	31.14	27.8	29.47
Albite	26.20	27.9	25.68
Anorthite	2.50		2.22
Corundum	0.31		1.12
Biotite		8.6	
Hypersthene	1.79		3.74
Magnetite	1.39	tr.	0.93
Ilmenite	0.76	tr.	0.61
Apatite	0.34	0.13	0.13
Calcite			0.20
Fluorite		1.00	0.51
Pyrite			0.02
Normative plagioclase	$Ab_{91}An_9$		$Ab_{92}An_8$
Symbol	I.(3)4.1″.3.		I.3(4).1″.3.

Iddings classifies this rock as a quartz-feldspar-porphyry having the composition of a granite. Washington lists it as a quartz porphyry having, under the "Qualitative System of Analyses," the symbol I.(3)4.1″.3. The name "llanite" is used for this rock by Iddings, and locally it is generally designated by the very descriptive name of "opaline granite."

Recommendations.—The opaline granite is extremely unusual in appearance and should have great value as a monumental and ornamental stone. Many of the outcrops examined are rather highly jointed, which may cause considerable waste in producing sound stone. The quarry west of Baby Head, however, contains much rock

[39]Washington, H. S., Chemical analyses of igneous rocks: U.S. Geol. Survey Prof. Paper 99, p. 119, 1917.

from which large blocks can be obtained. The opaline granite should be made available for those wishing a stone of distinctive and unusual appearance.

LOCALITY LL-36 (PAINT HORSE QUARRY)

Location and geology.—A granite mass and quarry are located 2.5 miles southeast of Lone Grove and about 1 mile from the nearest point on the railroad. The granite outcrop covers about 10 acres and is a low-lying dome which stands a little higher than the surrounding surface. It is a very coarse-grained pink granite which contains sufficient femic minerals to cause the granite to appear gray with a pinkish cast when viewed at a distance. Inclusions are absent, but aplite dikes are so numerous that considerable waste will be produced if the rock is quarried for building stone.

Megascopic description.—The granite is coarse grained, somewhat porphyritic, and light pink, mottled by dark-colored areas. The feldspar is mostly of a light pink color containing some orange, and some is milky white. The clear quartz is somewhat dark in appearance from internal reflections. The femic minerals are in clusters averaging about 10 mm. across. The milky feldspar and quartz areas are somewhat smaller in size. These minerals average about 8 mm. in size and form a mesh surrounding some groups and individuals of the large pink feldspars. The large feldspars average 22 mm. in length, and the largest one measured is 40 mm. long. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, biotite, and hornblende. Accessory minerals are magnetite, apatite, zircon, allanite, and titanite. Minerals formed by alteration are chlorite and sericite. The microcline and plagioclase are present in about equal amounts and are rather uniformly cloudy. Microperthite is well developed. The quartz has undulatory extinction and mosaic structure detectable when near extinction. Some reticulated quartz is present which contains long slender needles of rutile and plates of ilmenite. The plagioclase is oligoclase in composition.

Recommendations.—The granite is of a rather pleasing color and is present in sufficient quantities for all types of building and construction for which a coarse-grained granite of this type is suited. Aplites are sufficiently numerous so that considerable waste will be produced. The femic mineral areas are rather large, and consequently the stone does not take a uniformly good polish. The femic mineral areas are rather pitted on a polished surface, but the rest of the minerals take an excellent polish.

LOCALITY LL-41 (SANDSTONE MOUNTAIN)

Location and geology.—A sample of granite was obtained from a quarry on the eastern side of the granite mass known as Sandstone Mountain. The quarry is about 4 miles east of Llano and beside a graded road. The railroad is within 1.5 miles of Sandstone Mountain but is across Llano River from it. A large mass of fine-grained, pink granite which is almost free of inclusions composes Sandstone Mountain. Some pegmatites and aplites are present. Much of the rock at the surface on the mountain is highly jointed. Rather flat surfaces of granite exposed along the road are not nearly so highly jointed.

Megascopic description.—The granite is fine grained and light rose-colored. The principal mineral is light rose-colored feldspar. Quartz is abundant, and the femic minerals are rather scarce. The granite is rather uniform in texture and averages about 2.5 mm. in grain size. The minerals are mostly uniformly distributed except for the biotite which appears to be slightly more concentrated in some areas than in others. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are very scarce and consist of magnetite and a very small amount of zircon. Minerals formed by alteration are sericite and chlorite. The feldspars are very fresh and clear and are only slightly flecked by cloudiness. Some micropegmatite is present. The quartz has undulatory extinction and mosaic structure detectable when near extinction. The estimated mineral composition is microcline 25, plagioclase 37, quartz 37, and biotite 1 per cent. The plagioclase is oligoclase in composition.

Chemical analysis.—A chemical analysis of the granite and the normative mineral composition as calculated from the analysis are given in Table 31.

Table 31. Granite from Sandstone Mountain.

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	76.86	Quartz	35.34
Al_2O_3	13.26	Orthoclase	25.02
Fe_2O_3	0.19	Albite	34.06
FeO	0.51	Anorthite	3.34
MgO	0.13	Corundum	0.82
CaO	0.81	Hypersthene	0.96
Na_2O	4.01	Magnetite	0.23
K_2O	4.19	Ilmenite	0.15
H_2O+	0.11	Apatite	0.02
H_2O-	0.02	Fluorite	0.07
CO_2	0.07	Calcite	0.16
TiO_2	0.05	Pyrite	0.04
P_2O_5	0.01		
MnO	0.03	Normative plagioclase	$Ab_{91}An_9$
BaO	0.00	Symbol I.(3)4.1(2).3".	
F	0.03		
S	0.02		
	100.30		
Less O	0.02		
	100.28		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analysts: R. B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

The chemical analysis shows that this is a very good granite. It is a soda-potash granite.

Recommendations.—The granite is a very desirable monumental stone which is present as a large mass rather close to the railroad. It is also a good building stone, and there is sufficient of it for jetties and other structures where large tonnages of stone are needed.

LOCALITY LL–43

Location and geology.—A granite mass is located somewhere on the Fitzsimons Land and Cattle Company land north of the railroad and east of Graphite. Mr. Parkinson visited this granite mass during the early part of the building stone investigation and states that an acre or two of smooth stone is exposed sloping southwestward to a creek. An attempt to revisit this locality during 1940 was dropped when it was found that permission to enter the property had to be obtained through company headquarters in San Antonio. The granite is apparently of good grade and is probably similar to that described from the Kingsland Granite Company quarry (Ll–14). Granites of this type are abundant in the Llano area and it was deemed unimportant that the location be obtained, especially since securing permission to enter the land involved loss of time and unnecessary expense.

Megascopic description.—The granite is coarse grained, somewhat porphyritic, and light pink mottled with black and, to some extent, with milky white. Light pink and milky white feldspars are about equally distributed and are somewhat intermixed. The pink color of the feldspar has some orange in it. The femic mineral clusters and the quartz grains average about 7 mm. across and form a broken mesh around the feldspars which average about 21 mm. in length. The largest feldspars measure 30 mm. in length. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, hornblende, and biotite. Accessory minerals are magnetite, titanite, apatite, zircon, and allanite. An occasional grain of reticulated quartz is present containing long slender needles of rutile and plates of ilmenite. Much microperthite is present. The quartz has undulatory extinction and some mosaic structure detectable when near extinction. Minerals formed by alteration are sericite and chlorite. The feldspars are mostly clear with some flecks of cloudiness. The plagioclase is oligoclase in composition.

Recommendations.—The granite is of value for any of the uses for which a coarse-grained granite may be suited.

LOCALITY LL–44

Location and geology.—The small quarry on the Craig property from which the sample was obtained is located about 0.5 mile northeast of the railroad and about 1.5 miles in a northeasterly direction from Kingsland. The rock in the quarry has broken in long sweeping curves during the quarrying operation. Whether this is a property of the rock or faulty quarrying could not be determined. Some inclusions and a few pegmatites are present in the granite. The chief joint directions trend N. 55° E. and N. 50° W. The joints trending N. 55° E. are in part filled with mylonite.

To the north of the quarry, 0.5 mile, is the old Teiche quarry from which a church in Orange, Texas, was built. This quarry is located in a creek bed and is now filled with sand. In the acre or two of stone exposed along the creek, some inclusions are present, and several pegmatites were seen.

About 200 yards north of the Craig quarry a small amount of rock has been quarried from some surface sheets. A few inclusions and pegmatites are present. Only small exposures are present, but judging from their spacing and the shape of the hill, granite will be close to the surface over a large area.

Megascopic description.—The granite is somewhat porphyritic, fine grained, and pale pinkish gray. The light pink-colored phenocrysts of feldspar average 13 mm. in length, and the largest are about 20 mm. long. The minerals between the phenocrysts average about 2 mm. in size and consist of pale pink feldspar, milky white feldspar, quartz, and femic mineral groups. The femic mineral groups vary widely in size and some of the larger ones, which average about 4 mm. across, are irregularly distributed. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of plagioclase, microcline, quartz, hornblende, and biotite. Accessory minerals are titanite, magnetite, apatite, zircon, and augite. Minerals formed by alteration are chlorite and sericite. Some reticulated quartz is present which contains long slender needles of rutile and plates of ilmenite. The quartz has a small amount of undulatory extinction and a minor amount of mosaic structure detectable when near extinction. The feldspars vary considerably in cloudiness. Some of the plagioclase crystals are densely cloudy, others are flecked by cloudiness, and some are clear. The microcline is mostly only flecked by cloudiness. The plagioclase is oligoclase in composition.

Recommendations.—The granite is essentially gray streaked with pink. It is of rather an unusual color and might be of value as a monumental and building stone. The granite as quarried broke with a sweeping curve and may, therefore, be unsuited for quarrying. It is otherwise sound except for a few inclusions.

LOCALITY LL–45

Location and geology.—A low-lying granite mass is located about 5 miles southeast of Llano and 0.5 mile west of Sharp Mountain. It is located along a small drain about 100 yards south of the road. The road is graded for 3 miles and hard surfaced for the rest of the distance to Llano. Inclusions are absent, and a few pegmatites are present in the granite. The main set of joints trends N. 55° E. The outcrop is mostly in the form of very large boulders. Massive granite should be reached at a shallow depth.

Megascopic description.—The granite is fine grained and of a whitish-pink color. The minerals are uniformly distributed and are of uniform size, averaging about 3 mm. The feldspar varies between very pale pink and a pale orange-pink in color. Quartz is abundant, and bladed biotite is common. The mineral boundaries are short straight lines which give a graphic appearance to the granite. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are very scarce and consist of extremely small amounts of magnetite, apatite, and zircon. Alteration products consist of small amounts of chlorite and sericite. The feldspars are rather uniformly but not densely clouded. The quartz has marked undulatory extinction and marked mosaic structure detectable when near extinction. The estimated mineral composition is microcline 36, plagioclase 27, quartz 34, and biotite 3 per cent. The plagioclase is oligoclase in composition.

Chemical analysis.—A chemical analysis of the granite and the normative min-

North dome of Enchanted Rock showing typical exfoliation layers.

eral composition as calculated from the analysis are given in Table 32.

Table 32. Granite from near Sharp Mountain.

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	75.37	Quartz	32.46
Al_2O_3	13.68	Orthoclase	30.58
Fe_2O_3	0.21	Albite	30.92
FeO	0.64	Anorthite	2.78
MgO	0.19	Corundum	1.02
CaO	0.71	Hypersthene	1.29
Na_2O	3.63	Magnetite	0.23
K_2O	5.24	Ilmenite	0.15
H_2O+	0.13	Apatite	0.02
H_2O-	0.03	Fluorite	0.07
CO_2	0.11	Calcite	0.25
TiO_2	0.08	Pyrite	0.06
P_2O_5	0.01		
MnO	0.02	Normative	
BaO	0.00	plagioclase	$Ab_{92}An_8$
F	0.03	Symbol I."4.1".3.	
S	0.03		
	100.11		
Less O	0.02		
	100.09		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analyst R. B. Ellestad Fluorine determination by Willard and Winter method.

The chemical analysis shows calcite to be somewhat above the average for the central Texas granites, but otherwise this is a very good granite. It is a soda-potash granite.

Recommendations.—In color this is the lightest pink of the fine-grained granites and should be very desirable for a monumental and ornamental stone. It is exceedingly fresh and is composed of a group of minerals interlocked in such a manner that it is very strong and durable. The granite does not stand above the general ground surface, but there is a sufficient slope so that a quarry could be opened to a considerable depth without danger of flooding.

LOCALITY LL–62

Location and geology.—A granite mass located on the north slope of Hickory Mountain is about 6 miles airline from Llano and about 1.5 miles west of the Llano-Fredericksburg highway. Mr. Parkinson reports: "It is the best fine-grained pink granite in this area, and any sized block can be obtained. The joints are widely spaced. Inclusions are absent. Pegmatites and aplites are very scarce. The granite deposit is large, and the north half of Hickory Mountain is composed of it. The south half of the mountain is fine-grained gray granite, and the two granites at their contact show an interfingering relationship."

Megascopic description.—The granite is fine grained and of a dusty rose color. The feldspars are mostly dusty rose in color, and a few are milky white. The minerals are uniformly distributed and are of uniform size averaging about 2 mm. across. Feldspar is most abundant, quartz is abundant, and the femic minerals are rather scarce. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are magnetite, apatite, zircon, and an extremely small amount of allanite. Chlorite and sericite are rather abundant, and if it were not for the position of the sericite within plagioclase crystals, it might be mistaken for primary muscovite. The feldspars show a wide degree of clouding. Some of the plagioclases are highly clouded, and others are almost entirely clear. The microcline is mostly clear or only slightly flecked by cloudiness. The quartz has some undulatory extinction and some mosaic structure detectable when near extinction. The plagioclase is oligoclase in composition. The estimated mineral composition is microcline 25, plagioclase 30, quartz 42, and biotite 3 per cent.

Recommendations.—The granite is an excellent monumental and building stone. A large mass of it is present on the north side of Hickory Mountain, and it is favorably situated for quarrying.

LOCALITY LL–63 (ENCHANTED ROCK MASS)

Location and geology.—An enormous rounded dome of granite is located mostly in Llano County. The sample collected was near the Gillespie County line on the southwestern side of Enchanted Rock, which is about 23.5 miles from Llano by road, about 15 miles of which is hard surfaced. It is 19 miles from Fredericksburg by graded road. A map of the southern part of the Enchanted Rock granite mass in Gillespie and Llano counties (fig. 6) shows the exact location from which the sample was obtained. The bare granite surfaces in this area are shown by an intensified symbol.

The granite mass is about 425 feet in height above Sandy Creek at Enchanted Rock pavilion. It is the largest of a chain of granite knobs extending along the eastern and southern edges of a coarse-grained granite mass which is about 10 by 15 miles in size.

The frontispiece, Plate 2, is a photograph of the Enchanted Rock group of granite domes with Enchanted Rock located in the right background. Plate 3 is a photograph of Enchanted Rock showing remnants of exfoliation layers.

The sample was taken from a massive phase of the granite near a zone of highly jointed and faulted granite. The flow structure, which is difficult to ascertain on a weathered surface, is apparent upon fresh surfaces. At the place where the sample was taken the flow structure strikes N. 65° E. and dips 60° northwest. A vertical shear zone at least 20 feet wide is exposed in Sandy Creek. The granite in the shear zone has been reduced to a mylonite. Black streaks within the zone are somewhat similar to pseudotachylyte described by Shand[40] in Africa.

Megascopic description.—The granite is medium to coarse grained, somewhat porphyritic, and dark pink. The feldspar is predominantly dark pink containing considerable orange. A small amount of feldspar is ashy gray. The pink feldspars average about 17 mm. in length and are lath-shaped with a width of about 5 mm. The largest feldspar measured is 30 mm. in length. The femic minerals are rather uniformly distributed and average about 3 mm. in size. The quartz areas are more nearly equidimensional than are the feldspar areas. The average size of the nonporphyritic minerals is 5 mm. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. The accessory minerals are magnetite, apatite, fluorite, zircon, rutile, and allanite. Alteration products are sericite and chlorite. The feldspars are mostly clear with a few of the more basic plagioclase crystals being cloudy. Pleochroic halos are common in the biotite. The quartz has very little undulatory extinction. A few grains of reticulated quartz contain slender needles of rutile and plates of ilmenite. The plagioclase is oligoclase in composition.

[40]Shand, S. J., The pseudotachylyte of Parijs (Orange Free State) and its relation to "trapshotten gneiss" and "flinty crush-rock": Quar. Jour. Geol. Soc. London, vol. 72, pp. 198-221, 1916.

Chemical analysis.—A chemical analysis of the granite and the normative mineral composition as calculated from the analysis are given in Table 33.

Table 33. Enchanted Rock granite.

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	74.76	Quartz	33.12
Al_2O_3	13.16	Orthoclase	33.92
Fe_2O_3	0.40	Albite	24.63
FeO	1.51	Anorthite	3.34
MgO	0.28	Corundum	0.92
CaO	0.85	Hypersthene	2.68
Na_2O	2.94	Magnetite	0.70
K_2O	5.67	Ilmenite	0.46
H_2O+	0.15	Apatite	0.09
H_2O-	0.04	Fluorite	0.16
CO_2	0.06	Calcite	0.14
TiO_2	0.19	Pyrite	0.06
P_2O_5	0.04		
MnO	0.03	Normative	
BaO	0.03	plagioclase	$Ab_{88}An_{12}$
F	0.08	Symbol I.(3)4.1(2)."3.	
S	0.03		
	100.22		
Less O	0.05		
	100.17		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis Analysts: R B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

The chemical analysis shows that this is an exceptionally good granite. It is a soda-potash granite.

Recommendations.—The granite is an excellent building and monumental stone. The grain size is somewhat smaller and more uniform than that of most of the coarse-grained granites. There is an enormous amount of this stone available, and the mass is large enough for several quarries. The distance from a railroad is rather great; consequently this stone could not be used commercially at present except possibly as a building stone.

LOCALITY LL-68 (KINGSLAND GRANITE COMPANY QUARRY)

About 2.5 miles east of Graphite station and about one-fourth of a mile south of the Llano-Burnet highway (constructed 1940) is an abandoned quarry. A railroad spur a little over 1 mile long extends from the quarry to the main railroad. The granite is coarse grained and belongs to the Lone Grove granite mass. The quarry is in a low-lying outcrop. The stone is of good quality, but numerous aplites and pegmatites cause an undue amount of waste. The quarry is probably not suited for the production of building stone but should be advantageously situated to produce seawall and jetty blocks where pegmatites and aplites are not objectionable.

A few aplite and pegmatite directions noted are: N. 25° W., 70° NW.; N. 70° E., 80° NW.; N. 45° E., 30° NW. The thickest pegmatite seen is 18 inches, and most average 4 to 6 inches. Joints are not well developed, inclusions are absent, and crush zones were not found.

LOCALITY LL-69

A fine- to medium-grained red granite is located about 2 miles northeast of the Sixmile quarries and south of the Sixmile-Llano road. The granite is low lying, seldom projecting more than 3 feet above the general ground level. Five acres or more of granite with very little cover is present. Small shots to expose fresh granite have been made in several places. Near the northern side of the exposure the granite appears to have a grain size of about 2 mm. and is composed of pink and red feldspar with considerable quartz and some biotite as individual books and clusters of books up to 5 or 6 mm. in size. To the south about 200 feet the granite is of a deeper red and is somewhat more coarsely grained. Some pegmatites and aplites are present, but inclusions were not seen. Joints trend N. 65° E. and N. 25° W. and are rather widely spaced.

The granite, which is attractive, was examined in the field but was not otherwise tested, having been seen by the writer for the first time in October, 1940, after all testing by the Bureau of Engineering Research had been completed. Since that date, a quarry has been opened in the mass by Texas Quarries.

Mason County

LOCALITY M-3

Location and geology.—A granite mass is located 8.5 miles west of Mason along the Junction road and 1.5 miles east of Streeter. The sample was collected along the highway. This granite is 35 miles from the nearest railroad which is at Brady. The granite mass is about 1 mile wide and extends in a northeast-southwest direction for about 3 miles. McCammon[41] mapped this granite mass in connection with an examination for tin. His map, with some additions by the present writer, is reproduced as figure 8. On the western side Cambrian sandstone overlaps the granite, and to the east the granite is in contact with coarse-grained granite and Packsaddle schist. The granite has a few pegmatites in it which contain some topaz, tourmaline, and cassiterite. Small areas of Cambrian sandstone remain upon the schist just to the south of the granite. The granite outcrop is rugged, yet very large boulders are present, indicating that joints are not as closely spaced as in most of the fine-grained, pink granites examined.

Megascopic description.—The granite is fine grained and of a dusty coral color. The feldspar is of a dusty coral color and is the most abundant mineral present. Quartz is abundant, and the femic minerals are rather scarce. The minerals are uniformly distributed, are equigranular, and appear to measure about 3 mm. across. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, and quartz with a small amount of muscovite and biotite. Accessory minerals are fluorite and zircon. Fluorite is abundant and in many cases is situated within plagioclase crystals. A few of the fluorite grains are flecked in part by an intense purple color, and the rest of the fluorite grains are colorless. The biotite has almost entirely altered to chlorite and some sericite has developed by alteration of the feldspars, which are

[41]McCammon, J. H., Report on tin and magnesite deposits in Mason County, Texas: Univ. Texas, Bur. Econ. Geol., Min. Res. Circ. 32, p. 7, July, 1941.

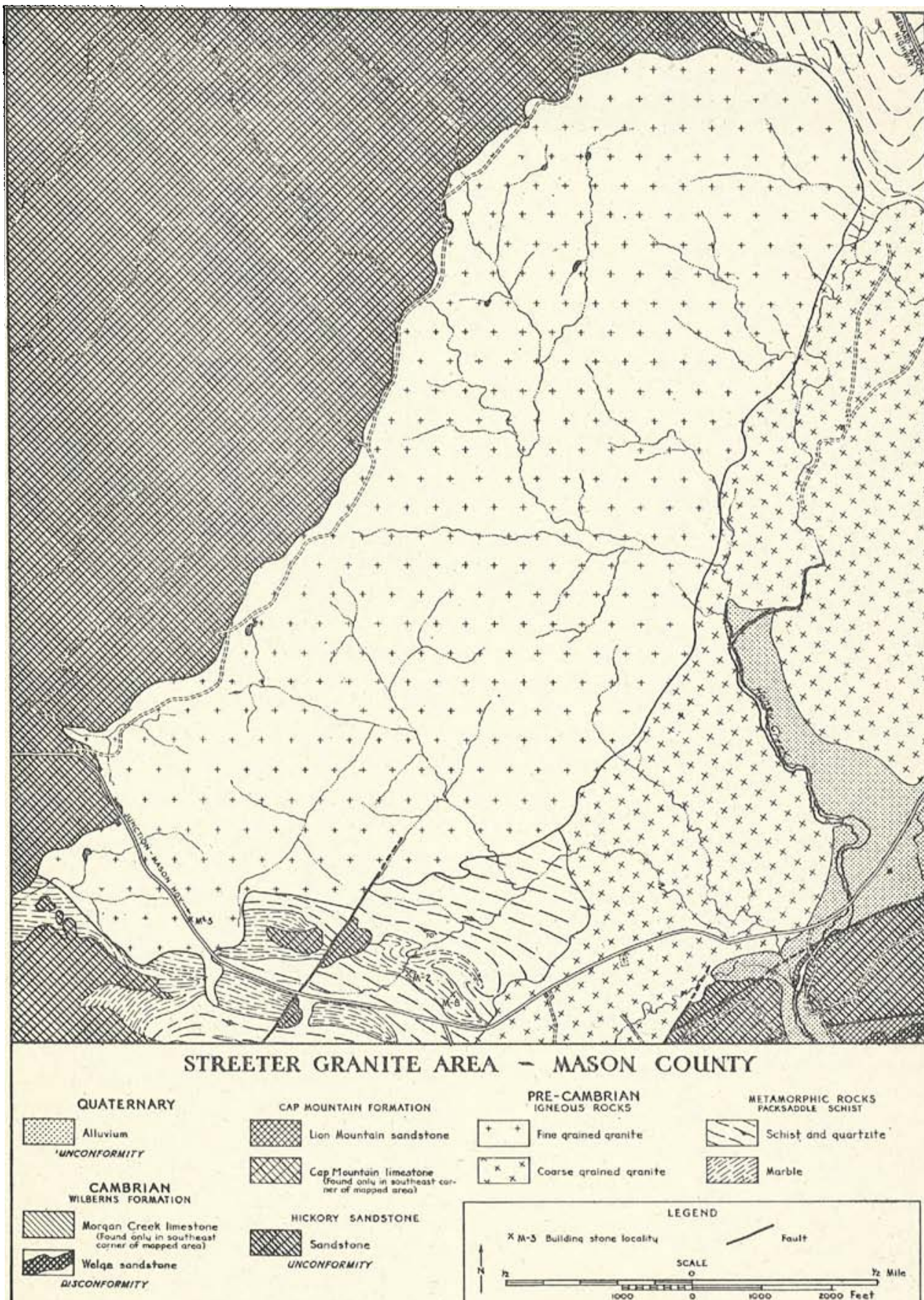

Fig. 8. Geologic map of an area east of Streeter, Mason County, Texas.

uniformly but not densely cloudy. The plagioclase is oligoclase in composition. The estimated mineral composition is microcline 30, plagioclase 40, quartz 29, and muscovite 1 per cent. The quartz has a small amount of undulatory extinction. Microscopically the granite is made up of grains less than 1 mm. in size, whereas megascopically the grains appear to be much larger.

Recommendations.—The granite is of value for building and monumental stone. Other granites of very similar appearance are located 30 miles closer to the railroad; consequently, this rock probably cannot compete with them at present. It is a sound stone composed of interlocking minerals and is undoubtedly very strong and durable.

LOCALITY M–4

Location and geology.—A granite mass is located 5.5 miles north of Mason along the hard-surfaced Mason-Brady highway. The distance to the nearest railroad, which is at Brady, is about 24.5 miles. The granite is a porphyritic border phase of the Katemcy granite mass in which feldspar phenocrysts up to 3 inches or more across are numerous. Some of the granite in this area appears to be contaminated by assimilated wall rock. The granite is not well exposed, being present mostly as intermittent outcrops for several hundred yards on each side of the highway and for a width of about 150 feet. The main joint direction is N. 25° W. The flow structure trends east-west and has a vertical dip.

Megascopic description.—The granite is porphyritic, coarse grained, and deep pink. Some phases of it have apparently assimilated schistose wall rock, and the mesh between the phenocrysts is dark and fine grained. The mesh is composed of quartz and femic mineral groups averaging 5 mm. across scattered through a mixture of 1 mm.-sized grains of pink feldspar, grayish-pink feldspar, quartz, and femic minerals. The fine-grained pink feldspar has a tendency to be aggregated as splotches within the mesh. The pink feldspar phenocrysts average about 26 mm. in length, and the largest measured are 55 mm. long.

In the granite containing less assimilation products, the mesh is composed of 5 mm.-sized grains of pink feldspar, quartz, and femic minerals. One feldspar phenocryst measures 50 by 55 mm. on a polished surface, and others were seen in the field that are considerably larger. Many of the phenocrysts have biotite sprinkled through them. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, quartz, plagioclase, and biotite. Accessory minerals are magnetite, apatite, zircon, titanite, and allanite. The allanite produces pleochroic halos in the biotite. The allanite has been altered until part of it is isotropic, and the rest is cryptocrystalline. No pleochroism is recognized. The titanite, which is very scarce, has been extensively altered to leucoxene which is associated with calcite. Some chlorite and a small amount of sericite are present. The feldspars are only slightly cloudy. The granite contains much microperthite and some micropegmatite. The large microcline phenocrysts have quartz, plagioclase, and biotite inclusions in a zone near and parallel to the outside of the crystal. Some of the quartz grains are reticulated and contain long rutile needles and plates of ilmenite. The quartz has a slight amount of undulatory extinction.

Recommendations.—The granite contains the largest feldspar phenocrysts of any granite examined. It is not uniform in composition, and much of it is darkened due to the assimilation of the near-by schistose wall rock. Its non-uniformity in color would be desirable for some uses, especially in combination with the large feldspar phenocrysts. The granite is not well exposed, and considerable stripping would be necessary to establish a quarry. The distance to a railroad is also great.

LOCALITY M–5

Location and geology.—A very large elevated mass of granite extends southward from Katemcy and is part of the Katemcy granite mass. The mass stands a hundred or more feet above the surrounding country and is estimated to cover several square miles of area. Brady, which is the nearest place on a railroad, is about 20 miles from the nearest point on this mass. The granite is 2 miles east of the hard-surfaced Mason-Brady highway.

The physical tests were made on a sample obtained about 0.5 mile southeast of Katemcy. The sample may not be representative of the entire exposure since it is within a few hundred feet of the contact of an older granite and may be finer grained than the average. The younger granite is somewhat porphyritic, with the feldspar phenocrysts averaging about 1.5 inches in length, a few being as much as 3 inches long. The best defined joint direction is N. 50° W., and another set trends N. 60° E. A long quartz vein trends N. 15° W. The flow structure trends about N. 20° W. and appears to dip at a low angle to the west. Inclusions are rare at the point where the sample was obtained but become much more numerous as the contact with the older granite is approached. For a distance of about 50 feet, the two granites are present in about equal amounts. The older granite is darker and fine grained with a few scattering phenocrysts up to about 1.5 or 2 inches in length. Several pegmatites in the older granite are deformed and are sharply cut off by the younger granite.

About one-half mile south of this locality, Cambrian sandstone containing numerous dreikanters[42] has been faulted against the granite.

Megascopic description.—The granite is coarse grained, porphyritic, and deep pink. The most abundant mineral is deep pink feldspar, the pink of which contains considerable orange. Clear quartz is very abundant, and femic minerals are common. The quartz is present as about 6 mm.-sized grains, some of which are adjacent, thus forming elongated quartz areas. The femic mineral groups are 2 to 3 mm. across and are fairly regularly distributed. The feldspar phenocrysts average about 17 mm. in length and are enmeshed by the other minerals. The largest feldspars measured are 35 mm. in length. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are very scarce and consist of magnetite, augite, zircon, fluorite, and altered allanite. Chlorite is common, and sericite is scarce. The feldspars are only slightly cloudy. The quartz has some undulatory extinction and a small amount of mosaic structure detectable when near extinction. A very small amount of micropegmatite is present. The microcline is somewhat perthitic. The plagioclase is oligoclase in composition.

Recommendations.—The granite is exceptionally fresh, and there is a tremendous amount of it present. It can be used for any purpose for which a coarse-grained pink granite is suited.

LOCALITY M-7

Location and geology.—A granite mass is located 4.5 miles west of Mason and 1.5 miles east of Grit. The sample was collected just south of the road. The granite is about 31 miles from Brady, which is the nearest point on a railroad. The granite is very light colored, somewhat porphyritic, and exposed in outcrops as much as 100 feet across. It covers several acres both north and south of the road. The outcrops are low-lying smooth surfaces. Joint directions trend N. 35° W. and N. 45° E. The flow structure trends between N. 70° W. and east-west. Mylonite seams are rather common and trend in many directions. Some mylonite seams as much as 1.5 inches thick are present. Inclusions consisting of graphite schist and amphibolite are rather scarce. Pegmatites and aplites were not seen.

Megascopic description.—The granite has a very unusual and pleasing color. The feldspars are very pale amethyst or amethystine-rose in color and are nearly equidimensional, averaging about 20 mm. in size. The abundant feldspars are surrounded in part by a mesh of quartz, milky white feldspar, and femic minerals. The clear quartz areas are irregular in shape and average about 7 mm. across. The femic mineral groups average about 4 mm. across and are uniformly distributed among the mesh minerals. The granite takes an excellent polish.

Microscopic description.—The granite is composed predominantly of microcline,

[42]Barnes, V. E., and Parkinson, G. A., Dreikanters from the basal Hickory sandstone of central Texas: Univ. Texas Pub. 3945, pp. 665–670, 1939.

plagioclase, quartz, and biotite. Accessory minerals are magnetite, apatite, and zircon. A very small amount of chlorite and sericite is present. Microperthite is abundant, and some micropegmatite is present. The microcline is clear, and the intergrown plagioclase is slightly cloudy. The plagioclase crystals are in part clear and in part cloudy and are oligoclase in composition. The quartz has undulatory extinction and mosaic structure detectable when near extinction.

Chemical analysis.—A chemical analysis of the granite and the normative mineral composition as calculated from the analysis are given in Table 34.

Table 34. Granite from near Grit.

Chemical analysis[a]	Per cent	Normative mineral composition	Per cent
SiO_2	71.14	Quartz	25.02
Al_2O_3	14.79	Orthoclase	33.92
Fe_2O_3	0.24	Albite	28.30
FeO	2.24	Anorthite	6.12
MgO	0.31	Corundum	0.82
CaO	1.34	Hypersthene	4.36
Na_2O	3.37	Magnetite	0.23
K_2O	5.69	Ilmenite	0.61
H_2O+	0.29	Apatite	0.19
H_2O-	0.05	Fluorite	0.16
CO_2	0.02	Calcite	0.05
TiO_2	0.28	Pyrite	0.04
P_2O_5	0.08		
MnO	0.05	Normative plagioclase	$Ab_{82}An_{18}$
BaO	0.13	Symbol I.4.″2.3.	
F	0.09		
S	0.02		
	100.13		
Less O	0.05		
	100.08		

[a] Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis Analysts: R. B. Ellestad (Fe_2O_3, FeO, CO_2, TiO_2, P_2O_5, MnO, and F); G. Kahan (all other determinations). Fluorine determination by Willard and Winter method.

The chemical analysis shows that this is an exceptionally good granite. It is a soda-potash granite.

Recommendations.—The granite has a pale amethystine color and is the lightest colored of the coarse-grained granites. It takes an exceptionally fine polish and is a very beautiful stone. This granite, even though it is 31 miles from the nearest railroad, should be made available. It is of great value as a building, ornamental, and monumental stone.

LOCALITY M–9

Location and geology.—A granite mass is located about 6 miles north of Mason and west of the old Katemcy road. The Mason-Brady highway is 1 mile to the west of the granite, but there is no direct road between the granite and the highway. The granite is about 26 miles by road from the nearest railroad, which is at Brady.

The granite is coarse grained and outcrops as a large elongated smooth dome-like knob. The more prominent joint directions trend N. 60° W., N. 45° E., and N. 35° W. Aplites are rather common. Those trending N. 60° E. dip 45° northwest, and those trending N. 10° E. dip westward. Quartz veins are not abundant, and those present mostly strike north-south and dip 60° to the west. The only pegmatite seen trends N. 60° W. and dips northeastward at an angle of 15°. Flow structure, indicated by aligned feldspars and a few schist inclusions, trends between N. 85° E. and N. 70° E. and has a vertical dip. Mylonite seams occupy some of the northeast-southwest joints, and one was seen which is at least 6 inches thick, with blocks of uncrushed granite completely surrounded by crushed granite. To the south, the granite is in contact with a fine-grained gneiss, the structure of which is essentially parallel to the edge of the granite and strikes N. 85° E.

Megascopic description.—The granite is coarse grained, porphyritic, and deep pink. The feldspar phenocrysts are deep pink containing considerable orange color. They average about 20 mm. in length, and the largest ones measured are about 40 mm. long. The phenocrysts are enmeshed by a 7 mm.-grained mixture of clear quartz, brownish-gray feldspar and femic minerals. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are magnetite, apatite, zircon, fluorite, titanite, and altered allanite. Some chlorite and sericite are present as alteration products. The feldspars are rather cloudy. Microperthite is common, and some micropegmatite is present. The quartz has a slight amount of undulatory extinction. Some of the quartz is reticulated, containing long hair-like needles of rutile and a few plates of ilmenite. The plagioclase is oligoclase in composition.

Recommendations.—The granite is suited for all the purposes for which a coarse-grained dark pink granite may be used. Similar granites are situated along railroads, whereas this one is 26 miles from the nearest railroad.

LOCALITY M–11

Location and geology.—A granite mass is located about 6 miles north of Mason and east of the old Katemcy road. The Mason-Brady highway is about 2 miles to the west, but there is no direct road between the granite mass and the highway. The granite is about 26 miles by road from the nearest railroad, which is at Brady. The mass of coarse-grained granite attains a height about 100 feet above the general land surface and is about 0.3 mile across and nearly a mile long. The outcrop trends about N. 45° E. The major joint directions trend N. 45° E. and N. 25° W. Other prominent joints trend N. 75° W. and N. 25° E. An aplite 5 feet thick, trends N. 10° W., and one 4 inches thick trends N. 50° W. Inclusions and pegmatites are scarce.

Megascopic description.—The granite is coarse grained, porphyritic, and deep pink. The feldspars are deep pink containing considerable orange color. The feldspars average about 22 mm. in length, and the largest ones measured are 40 mm. long. They are enmeshed by a 7 mm.-grained mixture of quartz, grayish feldspar, and femic minerals, all of which are somewhat aligned. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are magnetite, zircon, fluorite, and apatite. Minerals formed by alteration are chlorite and sericite. The feldspars are rather uniformly but sparsely clouded. Some of the quartz grains are reticulated containing long slender needles of rutile and plates of ilmenite. Microperthite is common, and micropegmatite is scarce. The quartz has undulatory extinction and mosaic structure detectable when near extinction. The plagioclase is oligoclase in composition.

Recommendations.—The granite is suitable for all purposes for which a coarse-grained, pink granite may be used. Similar granites are located along the railroad, whereas this one is 26 miles from the nearest railroad.

LOCALITY M–12

Location and geology.—A granite mass is located 1 mile west of the Mason-Brady road at a point 23 miles south of the railroad, which is at Brady. The granite sampled is a coarse-grained granite which is in contact with a fine-grained granite to the southeast. The contact between the two granites in a rather limited exposure trends N. 35° E. The main joint direction trends N. 10° W. Some sheet joints conform to the slope of the hill. One inclusion of the coarse-grained granite was found in the fine-grained granite, indicating that the fine-grained granite is the younger.

Just west of the ranch house and at the gateway leading into the pasture, fine-grained granite to the south is in contact with coarse-grained granite to the north. The contact at this point trends N. 85° W. Very little of the coarse-grained granite is exposed. The fine-grained granite contains numerous pegmatites.

Megascopic description.—The granite is coarse grained, porphyritic, and deep pink. The feldspar phenocrysts are deep pink with the pink containing considerable orange color. The feldspar phenocrysts average about 22 mm. in length, and the largest ones are about 45 mm. long. They are enmeshed by a mixture of quartz, deep pink feldspar, and femic minerals which average about 6 mm. in size. Rough pitted areas are present on the polished surface.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, and biotite. Accessory minerals are magnetite, fluorite, zircon, and allanite. Some chlorite and sericite are present. The feldspars are uniformly but not densely clouded. Some of the quartz grains are reticulated, containing long slender needles of rutile and a few plates of ilmenite. The quartz has strongly developed undulatory extinction and a marked development of mosaic structure detectable when near extinction. Microperthite is abundant, and micropegmatite is scarce. The plagioclase is oligoclase in composition.

A thin section was made of the fine-grained granite which intrudes the coarse-grained granite. It is composed predominantly of microcline, plagioclase, quartz, and biotite. The accessory minerals are magnetite, fluorite, zircon, and an extremely small amount of apatite. Only a very small amount of reticulated quartz was seen. The degree of distortion of the quartz is about the same as in the coarse-grained granite. The fine-grained granite is essentially the same as the coarse-grained except for a much smaller grain size and possibly a different proportion of minerals.

Recommendations.—The coarse-grained granite is very similar to that obtained from M–9 and M–11 and is of value for all purposes for which an unfinished coarse-grained pink granite may be used. A polished surface is apt to be pitted. Similar granites are located along the railroad, whereas this one is 24 miles from the nearest railroad.

LOCALITY M–16

Location and geology.—A granite mass located 4 miles south of Mason is 33 miles from the nearest railroad, which is located at Brady. The granite is medium grained and red. The freshest stone is located along a creek. The outcrop extends south of the creek for about 700 feet where it is overlapped by Cambrian sandstone. It is about 400 feet across. A pace-compass map of the outcrop area is shown in figure 9. The main joints trend N. 22° W. and N. 72° E. Other rather prominent joint directions are present. Inclusions are absent, and pegmatites are scarce. Most of the outcrop is highly weathered, and several feet of the surface stone would have to be discarded.

Megascopic description.—The granite has a grain size of 7 mm. and is rust-red. The feldspars are mostly rust-red, and a few are greenish brown. The quartz is slightly opalescent. The femic mineral groups and the quartz grains average about 4 mm. in size. The minerals are uniformly distributed. The granite takes a good polish.

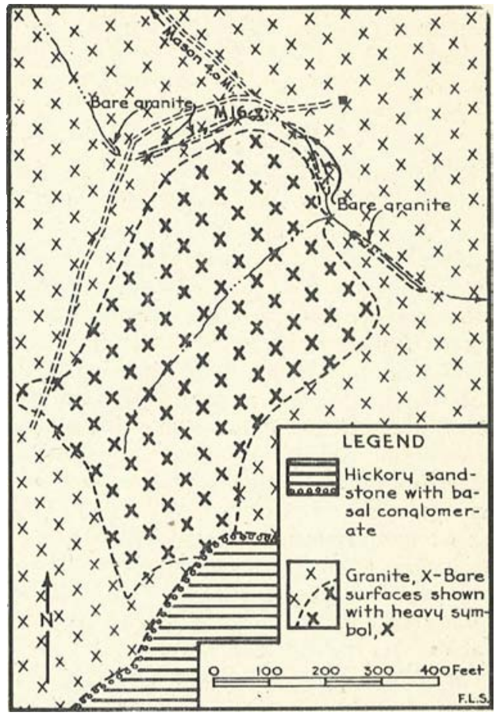

Fig. 9. Geologic map of an area 4 miles south of Mason, Mason County, Texas.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, biotite, and hornblende. The accessory minerals are magnetite, apatite, zircon, fluorite, and a few crystals of altered allanite. Minerals formed by alteration are chlorite, sericite, and calcite. The feldspars are exceptionally fresh. Micropegmatite and microperthite are common. Zones are present along some grain boundaries and across some large crystals in which finely crystalline quartz, plagioclase, and microcline are present. The quartz has some undulatory extinction and some mosaic structure detectable when near extinction. Microscopically nothing can be seen to account for the slight opalescence of the quartz. Inclusions in the quartz are relatively scarce, and most of those present appear to be apatite. A very small number of long slender needles present may be rutile.

Recommendations.—The granite is beautiful, but the presence of calcite is detrimental. The surface of the granite mass is highly weathered, and in general it is not favorable for quarrying. Also the granite is 33 miles from the nearest railroad.

LOCALITY M–17

Location and geology.—A granite mass is located 3.5 miles southwest of Fredonia near Spy Rock. The nearest railroad is at Brady, about 24 miles distant by road. The sample was collected from a small elliptical 100 by 150-foot dome which stands about 10 feet high. Many other small domes are located near by, and surrounding this area are many larger domes. The main joint directions are about N. 40° E. and N. 25° W. The granite varies considerably in grain size, and the sample is from a finer grained phase. Schist inclusions are present which are aligned in a north-south direction and have a vertical dip. A gash vein of quartz trends N. 40° E. Pegmatites are rather scarce.

Megascopic description.—The granite is medium to coarse grained and deep pink. The feldspars are deep pink flecked by coral-pink, the pink containing considerable orange. The feldspar individuals are not easily recognized but appear to be about 7 mm. in size. They are in continuous contact forming a mesh enclosing quartz areas averaging 5 mm. in size and femic mineral areas averaging 2 mm. in size. A small number of muddy-gray zonal feldspars are present which do not take a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, and quartz with a small amount of biotite. Accessory minerals are very scarce and consist of fluorite, magnetite, apatite, and zircon. Minerals formed by alteration are scarce and consist of chlorite and sericite. The feldspars are only slightly cloudy. Microperthite is abundant, and micropegmatite is very scarce. The quartz has undulatory extinction and some mosaic structure detectable when near extinction. The plagioclase is oligoclase in composition.

Recommendations.—The granite is situated rather far from improved roads and from the railroad. It is a fair building and monumental stone.

LOCALITY M–19 (FLATROCK GRANITE DOME)

Location and geology.—A large uniform, coarse-grained granite dome is located 3 miles west of Fredonia. It is 22 miles by road, none of which is paved, from the nearest railroad which is at Brady. The granite dome is estimated to cover an area of 50 acres and stands in height about 75 feet above the surrounding rather flat country. Joints are very widely spaced, and the main set trends N. 40° E., and another set trends N. 15° W. Inclusions are absent, and pegmatites are very scarce. Mylonite occupies many of the joints in the northwestern part of the dome. Flow structure in the granite is very indistinct.

Megascopic description.—The granite is coarse grained, porphyritic, and light pink. Most of the feldspar is light pink containing some orange. A small amount of feldspar is milky white. Clear quartz with a cairngorm color is very abundant. The femic mineral groups average about 5 mm. in size and in combination with quartz and white feldspar form a 7-mm. grain sized mesh about the porphyritic feldspar. The porphyritic feldspars average about 20 mm. in length, and some are as much as 40 mm. long. The granite takes a good polish.

Microscopic description.—The granite is composed predominantly of microcline, plagioclase, quartz, biotite, and hornblende. Accessory minerals are fluorite, magnetite, apatite, zircon, titanite, and allanite. Minerals formed by alteration are chlorite and sericite. Microperthite is abundant, and micropegmatite is rather scarce. The quartz is in part reticulated with long slender needles of rutile and abundant plates of ilmenite. Undulatory extinction is very pronounced in the quartz, yet mosaic structure is practically absent. The feldspars are only slightly cloudy. The plagioclase is oligoclase in composition. A crystal of allanite which is present in thin section is not greatly altered. It is sufficiently well preserved so that the optical properties could be determined and the mineral identified beyond doubt.

Chemical analysis.—A chemical analysis of the granite and the normative mineral composition as calculated from the analysis are given in Table 35.

Table 35. Flatrock granite.

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	75.11	Quartz	33.30
Al_2O_3	12.84	Orthoclase	32.80
Fe_2O_3	0.32	Albite	25.68
FeO	1.51	Anorthite	3.89
MgO	0.19	Corundum	0.31
CaO	0.98	Hypersthene	2.61
Na_2O	3.05	Magnetite	0.46
K_2O	5.47	Ilmenite	0.46
H_2O+	0.09	Apatite	0.09
H_2O-	0.03	Fluorite	0.16
CO_2	0.02	Calcite	0.05
TiO_2	0.19	Pyrite	0.04
P_2O_5	0.04		
MnO	0.03	Normative	
BaO	0.05	plagioclase	$Ab_{87}An_{13}$
F	0.18	Symbol I.(3)4.1(2).3.	
S	0.02		
	100.12		
Less O	0.08		
	100.04		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analyst: R. B. Ellestad. Fluorine determination by Willard and Winter method.

The chemical analysis shows that this is a very good granite. It is a soda-potash granite.

Recommendations.—The granite is very desirable, is fresh, and takes a good polish. It is part of a very large mass which is ideal for establishing a quarry. This granite, however, is located 22 miles from the nearest railroad.

BASIC ROCKS (PREDOMINANTLY NON-QUARTZOSE)

Resumé.—The basic rocks of central Texas are not well known. Paige[43] mentions them as follows:

> The dark intrusive rocks are most abundant in the southeast corner of the Llano quadrangle, but they have not been separately mapped except in one locality. A considerable mass of gabbro was observed in the vicinity of Goldmine Creek, north of the Moss ranch, and, as has been stated, some of the amphibolites included with the Packsaddle schist may represent old intrusives of gabbroic or diabasic type. In the area south of Click, especially, there are several bodies of very dark green to black amphibolite, probably derived from a gabbro or diorite magma. The talc deposits in this vicinity are presumably alteration products of such rocks. The serpentine rocks of Oxford are probably derived from peridotitic magmas.
>
> Two dark aphanitic dikes which cut the schists and which are apparently rather basic proved to be felsites, one a spherulitic mica felsite, the other a hornblende-mica felsite. The hornblende of the latter rock showed a bluish pleochroism parallel to the C axis, suggestive of a soda amphibole. Hornblende-soda granite forms a small intrusive mass a short distance east of Click.
>
> The rocks of this group were intruded earlier than the granites, but, though it is possible that those varieties of the granites which show evidence of pressure and metamorphism may be of nearly the same age, no relations were observed that might establish this point.

[43]Paige, Sidney, Description of the Llano and Burnet quadrangles: U.S. Geol. Survey Geol. Atlas, Llano-Burnet Folio (No. 183), p. 4, 1912.

Paige (p. 5) describes the petrographic character of a number of these rocks as follows:

Soda-hornblende granite (crushed), chip only, taken a short distance east of Click post office.

Microscopic character.—Holocrystalline; albite and considerable quartz, a little microcline. Large plates of green hornblende are abundant. Abundant titanite surrounding grains of titaniferous magnetite. The rock has suffered crushing, showing abundant granulation at the edges of the feldspar grains; the amphiboles are locally broken and bent and drawn into shreds.

Hypersthene-olivine gabbro, Goldmine Creek.

Megascopic character.—Dark blue to black medium-grained rock.

Microscopic character.—Holocrystalline texture. Labradorite in lathlike prisms, diallage, hypersthene, olivine. Biotite and hornblende poikilitically inclosing pyroxene and feldspar. Magnetite.

Amphibolite from high hill on Coal Creek.

Megascopic character.—Dark-green hornblende rock with slight tendency to cleave more easily in one direction than in another, due to pressure.

Microscopic character.—Mat of light-green hornblende with plagioclase in interstices. Shows evidence of crushing.

Metadiorite porphyry in hornblende schist series near Aaron Moss ranch.

Microscopic character.—Altered andesine-labradorite phenocrysts in a fine-grained groundmass of feldspar and green hornblende. Noteworthy flowage of hornblende around the phenocrysts of feldspar. Shows an intermediate stage in the formation of an amphibole schist.

Diorite from Cedar Mountain.

Megascopic character.—Medium-grained dark-gray to green rock.

Microscopic character.—Holocrystalline. Andesine-labradorite and hornblende in large plates.

Spherulitic mica felsite.

Megascopic character.—Black aphanitic dike rock.

Microscopic character.—Mass of very fine blades of biotite in groundmass of unstriated orthoclase. Some quartz and one quartz phenocryst, showing absorbed edges. A spherulitic arrangement of the feldspar is noteworthy and the mica seems to be arranged in a manner controlled perhaps by this spherulitic structure.

Amphibole (meta-gabbro?), partly crushed, from southwestern part of Burnet quadrangle.

Megascopic character.—Dark-green medium to fine grained hornblende rock.

Microscopic character.—Mass of interlocking hornblende crystals with interstices filled with untwinned plagioclase. Abundant grains of magnetite largely confined to the hornblende.

Mica-hornblende felsite.

Megascopic character.—Nearly black aphanitic dike rock.

Microscopic character.—Abundant hornblende in laths and grains set in a matrix of very finely granular feldspar and quartz. Biotite is also abundant in fine laths and tiny plates. Apatite needles are present. The hornblende has a blue pleochroism parallel to the elongation (C), and extinction angles as high as 18°.

Diorite southeast of Rough Mountain, west of San Fernando Creek.

Megascopic character.—Medium-grained dark-green rock.

Microscopic character.—Holocrystalline texture. Weathered andesine-labradorite and abundant hornblende in large plates. Much pyrite in large part confined to hornblende. Hornblende altering to iron oxide along cleavage cracks. Some epidote, some apatite.

The localities mentioned by Paige have not been visited by the writer.[43a] The diorite south of Llano is similar to the one which he mentions from Cedar Mountain. The metafelsite Ll–56 is similar to Paige's spherulitic mica felsite. The hornblendites of Gillespie County and Ll–64 may possibly be similar to Paige's "amphibolite from high hill on Coal Creek."

The serpentines described in this publication are probably derived from peridotitic rocks. They are not included in this section since they are changed (metamorphosed) from their original character and because serpentines commercially are included with the marbles.

[43a]Since this was written, the writer has mapped some of the localities cited by Paige. See Barnes, V. E., Soapstone and serpentine in the Central Mineral region of Texas: Univ. Texas Pub. 4301, pp. 55–91, 1943 [May, 1945].

An area of black gabbroic rock about 1 square mile in extent was found during June, 1941, while mapping was being done in Gillespie County. The gabbroic rock is situated along Crabapple Creek and is well exposed above and below the Shell Oil Company pipe line crossing. A microscopic examination of this rock has not been made. Megascopically it is greenish black to black and locally at least contains a high percentage of labradorite or a closely allied plagioclase feldspar. The mass is cut by numerous granite dikes, pegmatites, and aplites. Along Crabapple Creek some rather large surfaces free of these dikes are present. The joints range from closely spaced in much of the mass to widely enough spaced in other portions of the mass so that saw blocks could be obtained.

The location of the deposits described are shown in Plate 1 (in pocket).

Description by Localities

Diorite in Llano County

SAMPLE LL–61

Location and geology.—Diorite is exposed in a road material pit located at the intersection of the Sharp Mountain road with the paved Llano-Fredericksburg highway 2 miles south of Llano. The diorite is not exposed at the surface but is exposed at a depth of about 15 feet in the road material pit. Only a few fresh exfoliation boulders are present near the bottom of the pit, and the rest of the diorite is decomposed. Masses of graphite schist have been included by the diorite, and one inclusion of Oatman Creek type granite was seen. Small pegmatites cut the rock. The diorite described here is too weathered to be of value as a building stone. It is mentioned merely to make known the existence of diorite in the Llano area and not because this particular deposit is of commercial importance for building stone. The basic igneous rocks of the pre-Cambrian area of central Texas are mostly deeply weathered and are consequently not well exposed. They are probably more prevalent than hitherto recognized. Deposits of diorite suitable for building might be found by careful search.

Megascopic description.—The diorite is predominantly dark colored and contains abundant white feldspar as individual crystals and as widely separated groups of crystals. The biotite is in clusters of deep black crystals. The average grain size is about 2 mm. with some clusters of feldspar and biotite reaching as much as 1 cm. in size.

Microscopic description.—The diorite is composed predominantly of plagioclase feldspar, hornblende, and biotite. The plagioclase feldspar ranges in composition from near andesine-oligoclase to andesine-labradorite. A small amount of magnetite is present, but other accessory minerals are very scarce. Some of the biotite shows incipient alteration with the development of a green color, but none is altered to chlorite. Pyrite is scattered throughout the rock as small grains.

The estimated mineral composition is about plagioclase 50, hornblende 46, and biotite 4 per cent. It is a diorite, and since the predominant femic mineral is hornblende it is a hornblende diorite. The average plagioclase composition is andesine, which places it among the most common types of diorite.

A small outcrop of diorite is located about three-fourths of a mile eastward along the Sharp Mountain road. Microscopically it is similar to the diorite just described. However, some of the feldspar and biotite crystals are reticulate. The reticulate structure is mostly confined to the central portions of the larger crystals.

Recommendations.—The disintegrated diorite makes an excellent base course for highway construction, but this particular deposit is not of value for building stone. Other deposits which are not disintegrated might be found by careful search. The diorite is of a pleasing color and if found in large enough outcrops would be a valuable building stone.

LOCALITY LL–70

Location and geology.—A linear dike-like mass having a dioritic composition outcrops as a ridge just west of the road about 3 miles south of Click. The rock is fine grained and deep greenish black. Joints are numerous, and the ground is littered with blocks of the rock, mostly under 6 inches in size.

Megascopic description.—The rock was not polished, but judging from its mineral composition and the freshness of its minerals, it should take a good polish and be of a very dark green or greenish-black color.

Microscopic description.—The rock is composed of hornblende, plagioclase feldspar, magnetite, and some pyrite. Four thin sections of the rock from different parts of the mass give the following range in mineral composition:

	Per cent	*Average, Per cent*
Hornblende	35 to 82	54
Feldspar	10 to 61	42
Magnetite	1 to 8	4
Pyrite	Absent in three; 1 in fourth	

Accessory minerals are practically absent. The feldspar is near labradorite in composition. Many of the hornblende crystals are frayed at the ends and all are well aligned. The feldspar is mostly granulated with only occasional crystals retaining some semblance of twinning.

Recommendations.—The rock is much jointed and is of little value as a building stone. It might be of value for terrazzo chips and crushed stone.

Metafelsite in Llano County

LOCALITY LL–56

Location and geology.—Most of the metafelsite outcrops are located 2 to 3 miles southeast of Sixmile near the headwaters of Sixmile Creek. Figure 10 is a map of a portion of the area showing the location of several metafelsite outcrops.

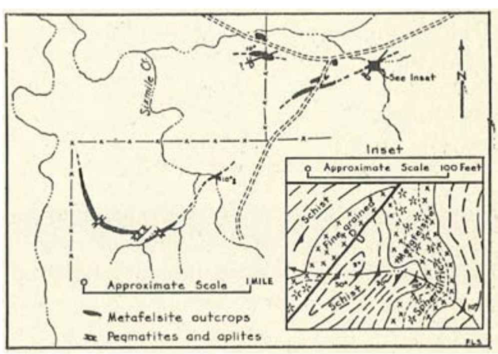

Fig. 10. Map of an area near the head of Sixmile Creek, Llano County, Texas, showing outcrops of metafelsite.

The metafelsite is in sheets ranging up to about 20 feet in thickness. It appears to be conformable to the enclosing schists, which are dark-colored biotite, hornblende, and some tourmaline schists. The borders of the metafelsite are fine grained with well-developed flow structure, and the central portions are spherulitic with the spherulites averaging about one-fourth of an inch in size. Openings which may be vesicules are rather common in the fine-grained rock just above the spherulitic portions but are not common near the upper contact. These rocks and the enclosing schists dip gently southward. Faults interrupt the continuity of the metafelsites, and granitic intrusives cut them. Whether this rock is a sill or a flow could not be definitely determined in the few hours spent in the examination. Detailed mapping is needed to settle this question. The metafelsite is much jointed and is hard.

Megascopic description.—The spherulites of the metafelsite average about 2 mm. in diameter and are deep greenish black. The mesostasis is gray. The fine-grained outer portion of the metafelsite is of about the same color as the spherulites and is not especially distinctive in appearance. The metafelsite takes a fair polish.

Microscopic description.—The central portion of the metafelsite mass is composed predominantly of spherulites in a limited amount of mesostasis. The spherulites are crowded by innumerable small biotite scales arranged in radiate and in parallel groups apparently along the cleavage of the enclosing mineral. The enclosing mineral is of low birefringence and has a refractive index less than that of Canada balsam. A very small amount of indistinct microcline twinning was seen, indicating that at least a portion of the mineral is microcline. Some of the mineral could be albite. The spherulites also contain a small amount of sericite and calcite. The mesostasis is composed of easily discerned grains of quartz, feldspar, calcite, and biotite. The dark color of the rock appears to be caused by the very numerous small scales of biotite. It is much more acid than its color would indicate.

Recommendations.—The spherulitic portion of the metafelsite is attractive. The joints are too closely spaced to allow it to be used for dimension stone. Its chief use would be for terrazzo chips, and this use would be limited because of the hardness of the rock.

Hornblendite in Blanco and Gillespie Counties

LOCALITY BL–25

Location and geology.—Several hornblendite outcrops are located just north of the large Blanco-Gillespie County serpentine mass. Figure 11 is a map of the hornblendite outcrops. The largest outcrop forms a high ridge trending northwest-southeast near the east bank of Big Branch in Gillespie County. The outcrop is about 2000 feet long and up to about 700 feet in width. Another high hill just west of Big Branch has a small outcrop of hornblendite at its summit. Two other smaller hornblendite outcrops are located about 1 mile to the east in Blanco County. The hornblendite has intruded Packsaddle schist.

Megascopic description.—The hornblendite is composed of crystals of hornblende a quarter of an inch in size. The rock was not polished, but from its appearance, it should take a good polish. The color of the rock is a deep greenish black.

Microscopic description.—The hornblendite is composed predominantly of hornblende and some plagioclase feldspar. Much of the hornblende is in large crystals little disturbed by shearing. Some of the hornblende is shredded and associated with feldspar which is somewhat granulated. Magnetite is present but is not plentiful. Several accessory minerals mostly of small size are distributed throughout the hornblende.

Chemical analysis.—A chemical analysis of a sample from the smaller hornblendite mass in Blanco County (Bl–25) and the normative mineral composition as calcu-

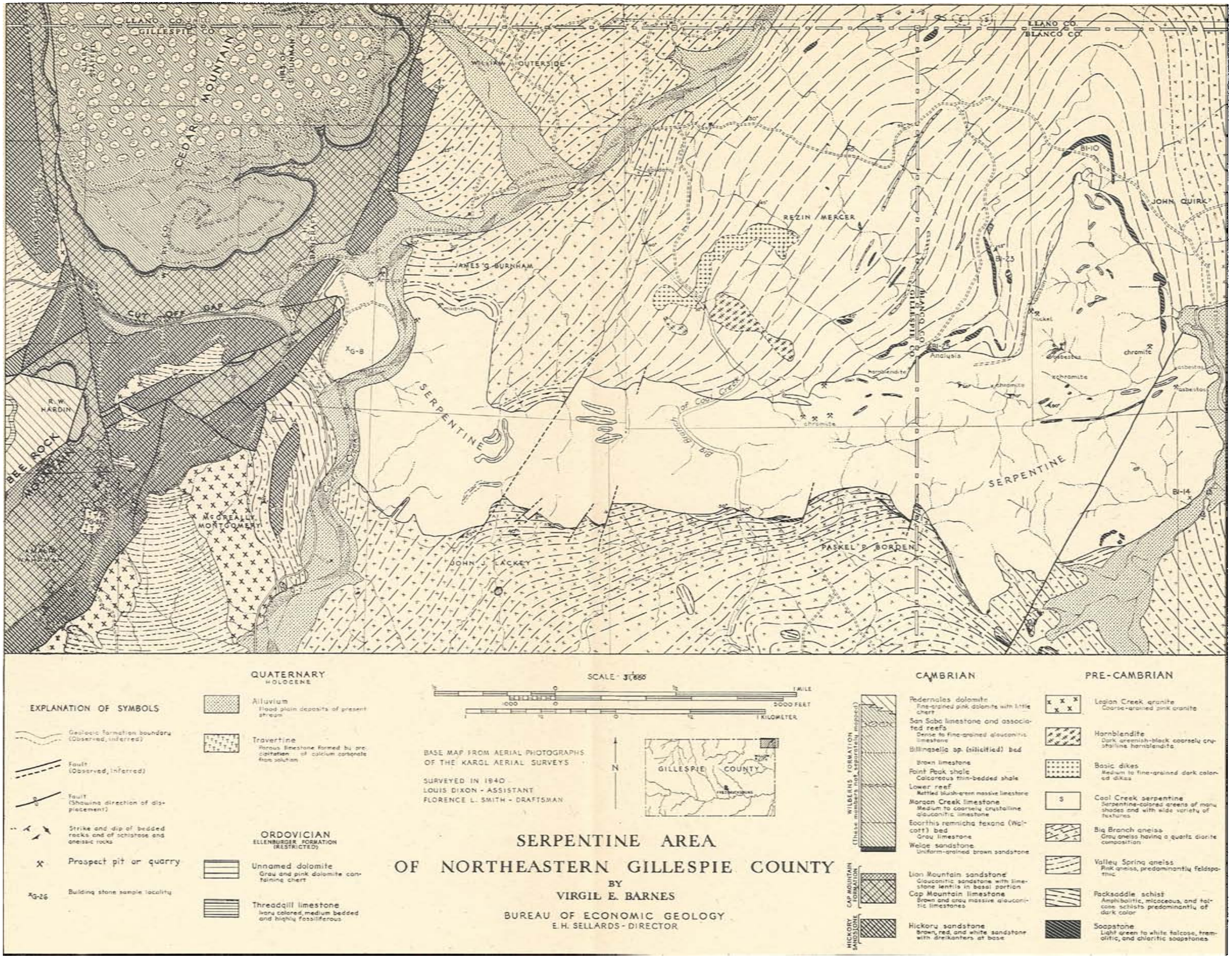

Fig. 11. Geologic map of the serpentine area in northeastern Gillespie and northwestern Blanco counties, Texas.

lated from the analysis are given in Table 36.

Table 36. Blanco County hornblendite.

Chemical analysis*	Per cent	Normative mineral composition	Per cent
SiO_2	50.00	Quartz	1.74
Al_2O_3	10.38	Orthoclase	1.11
Fe_2O_3	2.46	Albite	6.81
FeO	7.61	Anorthite	24.19
MgO	12.60	Diopside	31.23
CaO	13.02	Hypersthene	27.76
Na_2O	0.81	Magnetite	3.71
K_2O	0.25	Chromite	0.15
H_2O+	1.58	Ilmenite	0.91
H_2O-	0.05	Apatite	0.34
CO_2	0.06	Fluorite	0.07
TiO_2	0.56	Calcite	0.14
P_2O_5	0.11	Pyrite	0.04
Cr_2O_3	0.10		
MnO	0.21	Normative plagioclase	$Ab_{22}An_{78}$
F	0.03	Symbol	(III)IV.1".1.2.2.
S	0.02		
	99.85		
Less O	0.02		
	99.83		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analyst: R. B Ellestad. Fluorine determination by Willard and Winter method.

The normative mineral composition of the hornblendite does not compare with the modal mineral composition. The rock is composed mostly of hornblende, a very complex and variable mineral chemically, which contains most of the oxides calculated into the normative minerals quartz, orthoclase, albite, anorthite, diopside, hypersthene, magnetite, ilmenite, and fluorite. Of the minerals listed, those actually present in this sample, mostly in amounts less than stated, are plagioclase (albite plus anorthite), magnetite, chromite, ilmenite, apatite, calcite, and pyrite.

Recommendations.—A large amount of hornblendite is available. Joints are rather closely spaced at the surface limiting its use for building stone. It should be of value for terrazzo chips.

Hornblendite in Llano County

LOCALITY LL–64

Location and geology.—A hornblendite intrusive is located in the southwestern corner of Llano County one-half mile south of the Llano-Cherry Spring road at a point 26 miles southwest of Llano and about 21 miles from Fredericksburg. The road is graded for the entire distance to Llano but is otherwise unimproved. A map of a portion of the Enchanted Rock granite mass, figure 6, includes this mass of hornblendite. The hornblendite forms a low hill which trends in a northeast-southwest direction, passing at the southwestern end beneath the dreikanter-bearing Hickory sandstone. The hornblendite outcrop is about 1000 by 300 feet in size and is an intrusive in the Packsaddle schist. Tremolite asbestos is exposed in a pit at the southeastern margin of the hornblendite. The asbestos is in long curved masses, and the rock about it is rather highly sheared. The hornblendite has been used for terrazzo chips.

Megascopic description.—The hornblendite is even textured, medium grained, and deep green. It takes a good but not high polish. Light penetrates the surface somewhat, and through reflection and refraction a very attractive appearance is produced.

Microscopic description.—The hornblendite is composed predominantly of hornblende which approaches pargasite in optical properties. The hornblende is only slightly pleochroic and Ng is near 1.654. Magnetite is abundant as irregularly distributed grains and also as finely divided grains in some of the hornblende crystals. The hornblende is mostly in 2 or 3 mm.-sized crystals. Some zones are present in which the hornblende is crushed into lath-like splinters which are intermingled, forming a thatch-like aggregate.

Recommendations.—A rather large tonnage of hornblendite is available. Joints are closely spaced limiting its use as a building stone. It has been used for terrazzo chips and may be of value for other crushed stone products.

Metamorphic Group

MARBLES—INCLUDING SERPENTINE

PROPERTIES

Definition.—Marble is defined in its geologic sense as a crystalline rock composed essentially of calcite, dolomite, or a mixture of these minerals. Chemically it is similar to limestone and dolomite. The chief difference between marble and the limestone-dolomite group is the degree of crystallinity. Marble is considered to be a metamorphic rock derived by the recrystallization of limestone and dolomite. This definition might be broadened to include crystalline magnesite of the type found in the states of Washington and Texas.

Bowles[41] states: "In its commercial sense, the term has a much wider application. As susceptibility to polish is one of its chief commercial assets, all calcareous rocks capable of taking a polish are classed as marbles. Furthermore, serpentine rocks, if attractive and capable of taking a good polish, are so classed, even though containing little calcium or magnesium carbonates. . . ."

In this publication one other variety of marble is listed which has not yet been used commercially. In Llano County deposits consisting essentially of wollastonite and a variable amount of vesuvianite are present. The rock is white mottled with green and is a very attractive stone. The wollastonite marble is probably derived from impure limestone beds by contact metamorphism.

Mineral and chemical composition.—Marbles formed from limestones are composed chiefly of calcite (calcium carbonate), while those formed from dolomite are composed chiefly of dolomite (calcium-magnesium carbonate). These marbles may contain any proportion of dolomite and calcite. Another series of marbles exists, ranging in composition from dolomite to magnesite (magnesium carbonate), which have not been used extensively for building stones. Some magnesitic marbles of Texas are used for terrazzo chips.

Marbles may contain a wide variety of other minerals which are considered as impurities. The pre-Cambrian calcite and dolomite marbles of Texas contain tremolite, wollastonite, diopside, talc, serpentine, vesuvianite, quartz, feldspar, pyrite, and graphite. Bowles (p. 169) lists additional minerals found in marbles as follows: chert or flint, hematite, limonite, mica, chlorite, hornblende, and tourmaline. Other workers have listed many other minerals which are occasionally present.

[41]Bowles, Oliver, The Stone Industries, McGraw-Hill Book Company, New York, p. 168, 1934.

The chemical composition of marble is fixed by the minerals composing it. A pure calcite marble will contain between 95 and 100 per cent calcium carbonate, and a theoretically pure dolomite marble will contain 54 per cent calcium carbonate and 46 per cent magnesium carbonate. The impurities in marble stated chemically as oxides are chiefly silica (SiO_2), alumina (Al_2O_3), ferric oxide (Fe_2O_3), and ferrous oxide (FeO).

Serpentine marbles are composed predominantly of the mineral serpentine (antigorite), which is a hydrous magnesium silicate ($H_4Mg_3Si_2O_9$). This mineral is one of the end members of the chlorite group of minerals. Other molecules of the chlorite group are usually present in various amounts. An analysis of a Texas serpentine is calculated into the following amounts of the chlorite molecules:

	Per cent
Antigorite ($H_4Mg_3Si_2O_9$)	79.47
Magnesiocronstedtite ($H_4Mg_2Fe_2SiO_9$)	12.10
Amesite ($H_4Mg_2Al_2SiO_9$)	1.11
Nepouite ($H_4Ni_3Si_2O_9$)	0.51
	93.19

The balance of the rock is indicated to be:

	Per cent
Opal	4.72
Magnetite	1.39
Chromite	0.67
Pyrite	0.06
Calcite	0.14

Other minerals detected in serpentines of Texas are talc, scaly chlorite, and tremolite.

Texture, translucence, and color.—The texture of marble is governed by the size, form, and arrangement of the mineral grains of which it is composed. Both calcite and dolomite have three cleavage planes which may be detected by the bright reflections of light on fractured surfaces. These minerals tend to be equidimensional in size unless elongated by some deformative movement. Accessory minerals depending on their amount, size, and distribution have an influence on the texture of a marble. Marbles are usually described as fine, medium, and coarse grained. The pre-Cambrian marbles of Texas have an average grain size much larger than that of the Paleozoic marbles.

A fine-grained pre-Cambrian marble would have about the same grain size as a coarse-grained Paleozoic marble; consequently, such a statement of grain size is misleading. In this publication the actual average grain size or average range of grain sizes is given for each marble sampled unless the grain size is extremely small.

Bowles (p. 172) states: "Translucence is a measure of the capacity of marbles for transmitting light. The more translucent varieties, if fine-grained, are best adapted for novelties or other ornamental purposes. Some marbles look waxy, and this property seems to be related to translucence. The depth to which light will penetrate the best statuary marbles ranges from ½ to 1½ inches."

Bowles (pp. 171–172) discusses the color of marble as follows:

> The color of a marble, one of its most important physical properties, is governed by the nature of the constituents. Marbles consisting of pure calcite or dolomite are white, whereas green is the prevailing color of verde antique. Variations from the whiteness of a pure marble are due to admixtures of foreign substances. Such impurities may be distributed uniformly and thus give uniform coloration, or they may be present in bands or streaks, giving clouded or otherwise non-uniform colors. Very beautiful banded effects are obtained by sawing veined marbles in certain directions.
>
> The causes of some colors in marbles are easily determined. Black and grayish shades are attributed to carbonaceous matter, which is usually present as fine scales of graphite; red, pink, or reddish brown are due mainly to the presence of manganese oxides or to hematite; yellow-brown, yellow, or cream are caused by minute grains of limonite, a hydrous oxide of iron. Other colors, such as the bluish tint found in some beds of white marble, are difficult to explain.

Specific gravity, porosity, and strength.—The specific gravity of calcite is 2.715 and of dolomite 2.87. The specific gravity of a marble is, therefore, dependent on the specific gravity of its constituent minerals. In addition some porosity is present which tends to lower the specific gravity. Bowles states that marbles range from 165 to 180 pounds per cubic foot in actual weight.

The porosity of marble is usually low. The strength of marble is usually not significant, unless it is used in a place where it is subjected to excessive strains. The chapter in this publication on physical testing will deal in more detail with the specific gravity, porosity, and strength of marbles. Physical tests for the central Texas marbles are given in a separate chapter. They were not completed in time to be included under each locality described.

Structural features.—Joints are important in marble deposits. Closely spaced joints and numerous directions of jointing may make an otherwise desirable marble valueless. The best jointing pattern is one that is widely spaced, consisting of two sets of joints intersecting approximately at right angles.

The direction of easiest splitting of a marble, termed the rift or grain, is usually along the bedding in marbles which are not greatly deformed. In marbles subjected to metamorphism, additional minerals of a platy or elongated character may be formed which produce a direction of splitting other than along the bedding.

Some marbles are breccias which have been cemented by calcite. In others joints have formed which are filled with calcite. These veins of calcite may be very attractive if in certain patterns.

Bedding is an important feature in marbles. The beds must be thick enough to furnish standard saw blocks. Marble varies in many respects from bed to bed and these variations must be considered if a uniform product is to be produced. The failure of the marble industry in San Saba County can be accredited to a lack of knowledge of the variation from bed to bed of these marbles. "Bed" as used by the local quarryman denotes a bedding plane. In this publication, "bed" is used as defined in the Glossary of Mining and Mineral Industry, U. S. Bureau of Mines Bulletin 95, namely, "The smallest division of a stratified series, and marked by a more or less well defined divisional plane (bedding plane) from its neighbors above and below (Kemp)."

Pre-Cambrian Marbles of Central Texas

The marbles of the central Texas pre-Cambrian are widely different in texture, color, structure, and mineral composition from those of later ages. For this reason these marbles are discussed as a separate marble group. The mineral composition varies widely in these rocks, and for convenience of discussion the marbles are split into five groups based on the predominant mineral present. These groups are as follows: (1) predominant mineral calcite; (2) predominant mineral dolomite; (3) predominant mineral magnesite; (4) predominant mineral wollastonite; and (5) predominant mineral serpentine. The last two groups are not marbles in the geological sense but are included in the much broader classification of commercial marbles. Marbles in this area, composed predominantly of magnesite, will probably be used chiefly for other purposes than for building stone. Some of the Texas magnesite has been used for terrazzo chips.

The first four groups were originally limestones of varying degrees of purity. These limestones were changed to marble chiefly by dynamic metamorphism. The impurities in the limestone were changed to such metamorphic minerals as tremolite, wollastonite, diopside, talc, and vesuvianite. Some of the minerals such as the wollastonite, vesuvianite, and possibly others have been developed partly by contact metamorphism. The serpentine in these marbles is an alteration product of diopside.

The fifth group, the serpentine marbles, have developed by the alteration of basic rocks. The identity of the basic rocks from which the serpentines were developed has not been determined; however, the original rocks were probably pyroxenitic.

CALCITE MARBLES

Resumé.—Sixteen of the pre-Cambrian marble deposits sampled are composed predominately of calcite. Only four of these were free of dolomite, and these contained other minerals such as tremolite, wollastonite, diopside, and serpentine. Tremolite is widely distributed and was found in 11 marbles, talc in 8, diopside in 6, serpentine in 4, and wollastonite in 3. Pyrite was detected in 10 marbles of the group. Table 37 gives the minerals present in each deposit as determined by microscopic examination. The amount of material examined in each case is rather small in comparison to the size of the deposit; consequently, the list of minerals might be expanded considerably if each deposit were examined in detail.

Table 37. Mineral composition of central Texas pre-Cambrian calcite marbles.

Sample No.	Calcite	Dolomite	Tremolite	Wollastonite	Diopside	Talc	Serpentine	Pyrite
G–3	x		x		x			
Ll–1	x	x						
Ll–5	x	x	x			x		x
Ll–7	x	x	x					x
Ll–8	x	x	x					x
Ll–9	x		x				x	
Ll–11	x		x	x				x
Ll–20	x	x	x	x		x		x
Ll–27	x			x	x			x
Ll–42	x	x	x		x			x
Ll–53	x	x			x	x		x
Ll–58	x	x			x	x		
Ll–59	x	x	x		x	x	x	
M–2	x	x	x			x	x	x
M–8	x	x	x			x		x
M–10	x	x				x	x	

The silicate minerals in the marbles suggest that there is some correlation between the original composition and the present mineral content. If the original rock was poor in magnesium and contained silica, then the calcium silicate wollastonite might form. Where some magnesium was present but not enough to satisfy all of the silica, then in addition to wollastonite either or both diopside or tremolite might form. If sufficient magnesium were present, then wollastonite would not form and the silicate minerals formed would be tremolite, diopside and possibly talc, if conditions for the formation of hydrous minerals were present. In addition some material may have been introduced from the outside. The color of the marbles varies widely. Some of the dark gray to black marbles may be colored by minute particles of graphite included in the carbonate minerals.

The diverse mineral composition of the marbles affects their physical properties, as well as their ability to take a polish. Calcite takes the highest polish, followed by dolomite. The silicate minerals vary in their ability to take a polish, and of this group serpentine seems to be the least susceptible of taking a polish. Each of the minerals is of a different hardness; consequently, during the process of polishing, the hard minerals are brought into relief by the faster removal of the softer ones. Fortunately the marbles of central Texas have a fairly uniform distribution of their mineral content, and this feature seldom is noticeable.

The location of the following described deposits is shown in Plate 1.

Description by Localities

Gillespie County

LOCALITY G–3

Location and geology.—A marble deposit is located a short distance south of the Llano County line and about 1 mile east-southeast of Enchanted Rock. It is about 1 mile south of the Enchanted Rock road at a point 8 miles west of the Llano-Fredericksburg highway. The total distance from the marble deposit to the nearest railroad, which is at Llano, is 24 miles, 15 miles of which is hard surfaced. A map of the Enchanted Rock granite mass (fig. 6) includes the marble outcrop. The marble outcrops as an elliptical hill about 30 feet high. It extends for about 600 feet in a direction N. 60° E. and is about 100 feet wide. The main mass of marble is almost pure white and varies from fine grained to half-inch grained. On the north side of the hill the marble is paralleled by a rock containing much diopside. Many fine-grained pink aplitic dikes cut the marble.

Megascopic description.—The marble is light colored consisting of somewhat distorted narrow bands of white calcite, which polishes to a mirror-like surface, alternating with wide bands of light cream-colored fine-grained marble, which in reflected light reveals the presence of minerals of different hardness. Some of the marble is white with narrow gray bands. A photograph of a polished surface is shown in Plate 5. A number of small light brown irregularly distributed specks enhance the beauty of the stone.

Microscopic description.—The marble is composed of bands of relatively pure coarse-grained calcite alternating with fine-grained bands composed of calcite, diopside, and tremolite. The coarse-grained bands contain calcite crystals up to 3 mm. in size, but the average size is about half this amount. The calcite in the fine-grained bands averages about one-quarter of a millimeter in size, and the equidimentional diopside crystals average less than a tenth of a millimeter in size. The tremolite is mostly present in one-half millimeter-sized irregular areas, and much of it has diopside and calcite included within it.

Recommendations.—The marble is attractive, but the deposit is small and is located rather far from a railroad.

Llano County

LOCALITY LL–1

Location and geology.—A marble deposit located on the west bank of Sandy Creek about three-quarters of a mile north millimeter in size, and the equidimensional of the Llano-Round Mountain road crossing of Sandy Creek is about 8 miles south of the railroad at Kingsland, by road which is mostly graded but not otherwise improved. The main objection to this route is the absence of a bridge over Llano River. The distance by road to Marble Falls is about 17 miles.

The outcrop of marble is about 400 feet wide and is well exposed along Sandy Creek. A short distance from the creek the outcrop passes under a soil cover. The marble dips to the northeast between 15° and 30°. It is massive and somewhat banded. Its texture varies from fine to medium grained, and its color is a light bluish gray. The weathered marble has a sugary and in places splintery texture. A small number of thin quartz veins are present.

Megascopic description.—The marble varies in color from white to dark gray. Some is mottled with white on a gray background. The white areas are elongated and mostly parallel. Frosty appearing, roughly parallel incipient fracture lines traverse the marble. The surface except for these lines is mirror-smooth, and the penetration of light into the surface gives a depth of reflection which produces a surface of unusual brilliance.

Microscopic description.—The marble is composed predominantly of calcite and some dolomite. The grain size of the calcite varies widely, while that of the dolomite is much smaller and averages about one-third of a millimeter in size. The dolomite is concentrated in narrow parallel bands. The dolomite contains minute inclusions which probably give the stone its gray color.

Recommendations.—The marble takes a good polish and is of a pleasing color. The deposit is large and should be easy to quarry.

LOCALITY LL–5

Location and geology.—A deposit of marble crosses the Click Gap road about 100 yards north of Honey Creek. The deposit is about 14.5 miles southeast of Llano by road which is graded but otherwise unimproved. The marble band extends for a considerable distance each way from the road. It is narrow and only a small amount of stone could be quarried from it.

Megascopic description.—The marble is a banded gray stone, the bands of which vary from a slightly grayish white to almost black. An occasional narrow white calcite vein cuts the banding at a low angle. Some transverse whitish bands are shear zones in which the calcite grains are fractured. The mineral composition is such that the rock does not take a uniformly high polish.

Microscopic description.—The marble is composed essentially of coarse-grained calcite and fine-grained dolomite in about equal proportions. A small amount of tremolite and talc is also present. Very fine particles are included throughout the calcite and slightly larger ones are present in the dolomite. These particles were not identified. They are responsible for the smoky gray color of the stone. The marble also contains some pyrite.

Recommendations.—The marble takes a good polish but is of rather a somber color. The deposit is small and would be difficult to quarry. The stone is otherwise of excellent quality.

LOCALITY LL–7

Location and geology.—A marble band is exposed in a road cut about 200 yards north of Honey Creek on the Llano-Round Mountain road. It is located about 15 miles southeast of Llano by a road which is graded but otherwise little improved. The marble bed dips 50° S. 30° W. It is made up of rather thin beds which in places are contorted. It is probably a portion of the same marble bed mentioned under Ll–5. Considerable marble is available in this rather thin bed.

Megascopic description.—The marble is mostly banded and is light gray. Some elongated areas are a rather dingy white, and some rows of clear calcite crystals appear black. A few brown stains in the marble may be caused by decomposing pyrite. The marble takes a fair polish.

Microscopic description.—The marble is composed chiefly of calcite and some dolomite. Tremolite is rather abundant, and pyrite is scarce. The calcite varies widely in grain size and probably averages about 1 mm. in size. The dolomite grains are smaller and average about one-third of a millimeter in size. The tremolite is mostly in crystals which have a frayed appearance.

Recommendations.—Considerable marble is available in this rather thin marble band. Some imperfections are present which would limit its use.

LOCALITY LL–8

Location and geology.—A marble deposit is located a few hundred feet west of the road leading from Sandy Creek to Kingsland. It is about 5.5 miles south of the railroad at Kingsland, by road which is only slightly improved. Llano River, however, is not bridged on this route. The deposit is about 19.5 miles by road from Marble Falls and about 24.5 miles by road from Llano. Several beds of marble in this vicinity are shown in the Llano-Burnet folio of the U.S. Geological Survey. The marble is flat lying, and the outcrop examined ranges from rather thin bedded to massive. It is situated in an area of little relief and consequently is not well exposed. Some highly folded marble is located about 1 mile to the east. The folded marble is much jointed, limiting the size of block that can be produced. The pattern of folding is intricate, making the marble attractive.

Megascopic description.—The marble is composed of alternate narrow bands of white calcite and dark gray impure calcite.

The white calcite polishes with a mirror like surface, and the rest of the marble takes a less brilliant polish. As a whole the marble takes a very good polish and has a rather attractive appearance.

Microscopic description.—The marble is composed predominantly of calcite and contains some dolomite and tremolite. Pyrite in small grains is rather widely scattered throughout. The average calcite grain size is between one-half and 1 mm. in size, and the dolomite grains are slightly smaller. The tremolite is present as small blade- and lath-like crystals.

Recommendations.—A large amount of marble is present which takes a very good polish. It is of good quality, but marble of this type is now little used.

LOCALITY LL–9

Location and geology.—A deposit of marble is located about one-half mile west of the Sandy Creek–Kingsland road at a point 3 miles southwest of Kingsland. It is mapped in the Llano-Burnet folio. The marble is almost flat lying with some minor folds. A rather large area of it is exposed.

Megascopic description.—The marble has a somewhat mottled appearance with a combination of clear to white calcite areas, light buff or yellowish serpentine areas, and somewhat deeper brown serpentine areas. These colors are evenly distributed, giving the rock a granular rather than a banded appearance. The calcite polishes to a mirror-like surface, and the serpentine becomes matt and is depressed somewhat below the calcite surface.

Microscopic description.—The marble is composed predominantly of calcite and serpentine and a small amount of tremolite. The serpentine is in rounded grains, suggesting that it is an alteration product of diopside.

Recommendations.—A large amount of marble is present which is of rather attractive appearance. The serpentine polishes low; consequently, the marble does not take a brilliant polish. It appears to be of good quality.

LOCALITY LL–11

Location and geology.—A deposit of marble is located about 100 feet south of Honey Creek and only a short distance south of a marble already described under LL–5. It is about 14.5 miles southeast of Llano by road which is graded but otherwise unimproved. The marble is dark colored and veined. Only a small amount of it outcrops, but with sufficient prospecting more might be found.

Megascopic description.—The marble is banded and dark gray. Some bands are almost white and others are white tinged with yellowish brown. The majority of the bands range from medium to dark gray. Transverse light-colored bands are probably incipient shear zones. The marble takes a good polish.

Microscopic description.—The marble is composed predominantly of calcite, some tremolite, and a small amount of wollastonite. The calcite grains are elongated and average about 1 mm. by one-third of a millimeter in size. The tremolite is mostly in small lath and scale-like grains. The marble contains some pyrite.

Recommendations.—The marble takes a good polish and is probably of good quality. The amount present appears to be limited.

LOCALITY LL–20

Location and geology.—A marble deposit is located about 1 mile east of the Llano-Fredericksburg highway at a point about 4 miles south of Llano. It outcrops on the west bank of Oatman Creek and is well exposed for an area of about 30 by 40 feet in Oatman Creek. Joints are scarce, and the marble is massive. Much of the marble is banded, and the bands are contorted. To the east the marble is in contact with amphibolite which dips 30° N. 70° E. To the north, granite cuts across the marble abruptly terminating it. The marble was not traced to the south.

Megascopic description.—The marble is highly banded and contorted. The bands range in color from grayish and brownish white to very dark gray. The brownish color may be a weathering stain which will not be present at depth. The marble does not take a high polish.

Microscopic description.—The marble is composed of calcite, dolomite, tremolite, wollastonite, and talc. More than half of the rock is calcite. Dolomite and tremolite are abundant, and wollastonite, talc, and pyrite are present in minor amounts. The silicate minerals are bent and crushed, indicating that some of the deformation of the marble took place after their formation.

Recommendations.—The marble does not take a good polish. It may otherwise be of good quality but is situated in a low area where it is subject to floods. The outcrop is small, is cut off in one direction by granite, and in the other is covered by alluvium.

LOCALITY LL–27

Location and geology.—A marble deposit is located about 5.5 miles south of the Llano-Cherry Spring road at a point about 11 miles from Llano. The road is mostly graded but otherwise unimproved. The marble strikes about N. 50° E. A quarry for producing terrazzo chips is about 20 by 50 feet in size. The marble is of a pale bluish color and is coarse grained. The wollastonite forms raised areas on weathered surfaces.

Megascopic description.—The marble is predominantly white with an irregularly distributed ice-blue cast. Areas up to 2 inches in size are more or less radial in structure. A photograph of a polished surface of this marble is shown in Plate 5. The rest of the marble is medium to coarse grained. It takes a rather dull polish, which, however, is unnoticed because of its unusual and attractive color.

Microscopic description.—The marble is composed predominantly of calcite, considerable wollastonite, a small amount of diopside, and a very small amount of pyrite. The wollastonite is in narrow bands throughout the rock. The diopside is in grains of one-fourth of a millimeter in size, mostly surrounded by calcite. The calcite grains range up to about 4 mm. in size.

Recommendations.—The marble is not well exposed except for a limited area about the quarry. The amount available may be limited, but the quality is good. The color of the marble is very attractive, and the surrounding area should be prospected for larger deposits.

LOCALITY LL–42

Location and geology.—A marble deposit is located 2 miles northwest of the Llano-Cherry Spring road at a point 11 miles from Llano. Twelve miles of the road is graded but not hard surfaced. The last mile to the deposit is along a pasture road which is not improved. Except for about 200 yards of trenching, the marble is poorly exposed. The trenching, done by the U.S. Gypsum Company many years ago, exposes a large amount of marble ranging in color from white to blue-gray. It is coarse grained, ranging up to about half an inch in grain size. A pit about 40 feet deep in one of the trenches evidently ended in pegmatite since pegmatite is the last material placed on the dump. The blue marble when struck by a hammer gives off a stifling fetid sulphurous odor. Marble of this type would be very objectionable to quarry and finish.

Megascopic description.—Marble of two different colors compose the deposit. One type is coarse grained and white; the other is medium to coarse grained and bright light gray to blue-gray. (See Pl. 5.) The white marble has a few zones containing some black specks. These marbles are uniform in color and take a mirror-like polish.

Microscopic description.—The marble is composed essentially of calcite and dolomite. The dolomite is rather uniformly distributed as 1.5 mm.-sized grains surrounded by calcite which has a somewhat larger grain size. The marble contains a very small amount of diopside and pyrite and possibly a small amount of tremolite.

Recommendations.—The marble has a pleasing color and takes an excellent polish. The blue-gray type would be objectionable to work because of the stifling fetid odor emitted when struck. It is a desirable building and monumental stone.

LOCALITY LL–53

Location and geology.—A marble deposit is located about 1 mile south of the

Llano-Cherry Spring road at a point about 3 miles southwest of Llano. The marble dips approximately 60° to the east and forms a low ridge, the highest point of which is composed of blue marble which gives a fetid odor upon being struck. A short distance to the south about 2 carloads of marble have been quarried for terrazzo chips. The sample tested was obtained 400 feet south of the terrazzo chip quarry from a slightly banded light-colored outcrop of marble. A pit a few hundred feet farther south is in a light-colored banded marble which contains a brown-stained layer of silicates. The stain is probably from decomposed pyrite.

Megascopic description.—The marble is predominantly light colored and somewhat banded. Some bands are white and others are light bluish gray speckled by small flea-brown areas. The banding is gradational with large intermediate colored areas having a brownish tint produced by the flea-brown specks. Some narrow white veins traverse the marble. The flea-brown areas and dolomite rhombs are harder than the enclosing calcite and cause some relief which detracts from the high polish of the calcite. The marble is slightly translucent, and some reflection from cleavage planes of calcite produces points of brilliance.

Microscopic description.—The marble is composed predominantly of calcite. Some dolomite and a small amount of pyrite are present. The silicate minerals are not abundant and are limited to talc and diopside. The diopside has a light yellow pleochroism, suggesting that it is a somewhat ferriferous member of the diopside-hedenbergite series. The grain size of the calcite probably averages about 1 mm.

Recommendations.—The marble deposit is large. Much of the marble is of a pleasing color, takes a fair polish, and is an excellent building stone. It has been used for terrazzo chips.

LOCALITY LL–58

Location and geology.—A marble deposit is located at the western foot of Bachelor Peak about 2 miles west of the Llano-Fredericksburg highway at a point about 4 miles south of Llano. The marble bed was mapped by Paige.[45] A small amount of marble was quarried here about 1890, and the quarry is known as the old Courthouse quarry. The marble is massive, well crystallized, slightly banded, and of a light color. A 45-foot bed of marble is exposed in a small creek a short distance to the south. This may be a continuation of the bed upon which the quarry is located. Another marble bed from which stone has been used for terrazzo chips is located about a mile to the southeast. It is a few hundred feet east of the foot of Hickory Mountain. Some of the marbles are fine grained and white, and others are blue. Much of the marble, however, contains silicates and is not of a pleasing color.

Megascopic description.—The marble was not polished, but on rough surfaces it is of a white color with a small amount of light gray banding.

Microscopic description.—The marble is composed predominantly of calcite and a very small amount of dolomite. The silicate minerals are rather scarce and consist of diopside and talc. The calcite and dolomite grains range mostly from 1 to 2 mm. in size.

Recommendations.—The marble is lighter colored than many of the marbles of central Texas. It is not well exposed but is probably present in sufficient amount to be quarried. It is a very good building and monumental stone.

LOCALITY LL–59

Location and geology.—A marble deposit is located along the Valley Spring road 6.7 miles northwest of its intersection with the hard-surfaced Llano-Cherokee highway, 3.5 miles north of Llano. The Valley Spring road is graded but otherwise unimproved. The marble crosses the road in a north-south direction. It was traced for about 500 yards southward and continues northward but was not followed in that direction. The outcrop is about 500 feet wide. The color ranges from white to a bluish and a grayish white. The grain size ranges from fine to coarse. A

[45]Paige, Sidney, Description of the Llano and Burnet quadrangles: U.S. Geol. Survey Geol. Atlas, Llano-Burnet Folio (No. 183), 1912.

small amount of bluish marble is present which gives off a fetid odor when struck.

Megascopic description.—The marble was not polished. A rough surface is slightly banded and is grayish white.

Microscopic description.—The marble is composed predominantly of calcite and only slightly less dolomite. Silicate minerals are not abundant. They consist mostly of tremolite and serpentine and a small amount of talc and diopside. This is rather a coarse-grained marble containing some grains as much as 5 mm. in size.

Recommendations.—The marble deposit is large. Much of the marble is of a desirable color, of good quality, and is a desirable building and monumental stone.

Mason County

LOCALITY M–2

Location and geology.—A marble deposit is located just north of the Mason-Streeter road at a point about 8 miles west of Mason. The nearest railroad to this deposit is at Brady, a distance of about 34.5 miles. A map of the area is shown in figure 8. The marble bed sampled is only one of several in the area. Another bed is located just south of the highway. The largest area of pre-Cambrian marble yet encountered in central Texas is located south of the area mapped and is well exposed 1 mile south of Streeter. Massive marble outcrops are exposed for several thousand feet along the streams.

The marble bed sampled extends in an east-west direction and has two small areas of Cambrian sandstone on it. The western end of the marble bed is abruptly terminated by a crosscutting fine-grained granite, and the eastern end is terminated by a large mass of coarse-grained granite. The marble is interbedded with quartzites and schists, and the whole has been highly folded and contorted.

Megascopic description.—The marble is grayish black and is veined by numerous narrow irregular white calcite veins. Narrow crush zones cross the marble in which the disturbed calcite is of slightly lighter color. The marble takes a somewhat dull polish.

Microscopic description.—The marble is composed predominantly of calcite and a very small amount of dolomite. A small amount of talc, tremolite, pyrite, and serpentine is also present. Hydrochloric acid freed a dark-colored material, probably graphite, which adheres to the bubbles and collects on the surface of the solution. The calcite and dolomite average about 1 mm. in grain size.

Recommendations.—Abundant marble of good quality, but of a sombre color, is located in this area. It could be used as a building stone.

LOCALITY M–8

Location and geology.—A second marble sample was collected a short distance to the east of and from the same marble band described under M–2. A map of the area is shown in figure 8. This marble may be slightly more massive than that described under M–2, but otherwise it is essentially the same.

Megascopic description.—The marble is rather dark gray and is veined by numerous white calcite veins which trend in several directions. Pyrite is quite abundant. The marble takes a somewhat dull polish, and the calcite veins take a high polish.

Microscopic description.—The marble is composed predominantly of calcite and a very small amount of dolomite. Tremolite, talc, and pyrite are rather abundant. The marble is composed mostly of grains one-half of a millimeter in size. Some of the calcite grains range up to 2 or 3 mm. in size.

Recommendations.—The same recommendations are made for this marble as for M–2.

LOCALITY M–10

Location and geology.—A marble deposit is located about 5.5 miles northeast of Mason and about 0.5 mile west of the Fredonia road. The nearest railroad to this deposit is at Brady, a distance of about 30 miles. The marble is poorly exposed and is present as scattering small outcrops over an area about 400 feet wide and several hundred yards long. A shaft in the marble sunk to a depth of about 15 feet exposes beds dipping 55° N. 10° E. The strike of the marble changes rapidly because of folding. The marble is in open folds at the western end of its outcrop and becomes rather closely folded to the east. The marble is gray, banded, and somewhat jointed. Several silicate streaks containing wollastonite, garnet, and vesuvianite were seen within the marble. Both to the north and south the marble is bordered by amphibolite crosscut by pegmatites.

Megascopic description.—The marble is somewhat banded with colors ranging from very light gray to medium gray with some bands having a definite yellowish-green color. The marble takes a somewhat dull polish.

Microscopic description.—The marble is composed predominantly of calcite and dolomite. The silicate minerals serpentine and talc are rather abundant. The serpentine is mostly in rounded grains one-fourth of a millimeter in size which suggests that the serpentine has been derived by the alteration of diopside. The carbonate minerals are mostly in millimeter, or less, sized grains with some calcite grains ranging up to several millimeters in size.

Recommendations.—The marble takes a somewhat dull polish and in general is not of an especially pleasing color. Silicate minerals are rather numerous, and at the surface joints appear to be rather closely spaced. Better marbles are located nearer to railroad transportation.

DOLOMITE MARBLES

Resumé.—Six deposits of marble examined are composed predominantly of dolomite. All of them contained a variable amount of calcite. In addition to the carbonate minerals, five deposits contained diopside and pyrite, four contained serpentine, two contained both wollastonite and talc, and one contained tremolite. A resumé of the mineral composition of these marbles is given in Table 38.

Table 38. Mineral composition of central Texas pre-Cambrian dolomite marbles.

Sample No.	Calcite	Dolomite	Tremolite	Wollastonite	Diopside	Talc	Serpentine	Pyrite
Bu-10	x	x						
Ll-6	x	x	x		x			x
Ll-18	x	x			x		x	x
Ll-34	x	x			x		x	x
Ll-54	x	x		x	x	x	x	x
Ll-55	x	x		x	x	x	x	x

With few exceptions the same remarks hold for the dolomite marbles as for the calcite marbles. There is an excess of magnesium in these rocks as evidenced by the preponderance of dolomite. However, two of these marbles contain wollastonite, a calcium silicate.

Chemical analyses of dolomitic marbles from the Sharp Mountain area, Llano County, are given in Table 39. One of

Table 39. Chemical analyses of dolomitic marbles of Sharp Mountain area, Llano County; E. P. Schoch and J. E. Stullken, analysts.[46]

	C4308	C4312	C4318	C4319	C4320	C4321	C4322
MgO	19.55	20.72	18.56	19.30	19.62	20.84	19.89
CaO	29.74	30.11	31.30	28.21	29.58	30.62	27.77
$Al_2O_3+Fe_2O_3$	2.91	1.70	2.45	2.98	1.91	1.03	2.94
SiO_2	2.88	3.55	1.24	12.06	8.06	0.40	15.16
CO_2	44.67	44.15	44.81	36.55	39.91	46.11	34.10
Ignition loss	0.19	0.09	1.67	0.57	0.47	1.48	0.21
Total	99.94	100.32	100.03	99.67	99.55	100.48	100.07

C4308. From Elmore Stewart property, about 2 miles east of Llano-Fredericksburg highway and 50 steps south of cattleguard across Sharp Mountain road.

C4312. From Hammond property and Dezendorf terrazzo chip quarry near northeastern end of Sharp Mountain, about 6 miles from Llano (Ll-6).

C4318. From Stribling property, near southwestern end of Sharp Mountain and 75 steps northwest of E. B. Snead terrazzo chip quarry.

C4319. From Stribling property, about 0.7 mile southwest of E. B. Snead terrazzo chip quarry and near the southwestern end of the marble outcrop.

C4320. From Stribling property, about 0.5 mile southwest of E. B. Snead terrazzo chip quarry and 75 steps south of western test pit.

C4321. From Stribling property, about 0.5 mile southwest of E. B. Snead terrazzo chip quarry and from western test pit.

C4322. From Stribling property, about 0.5 mile southwest of E. B. Snead terrazzo chip quarry and from eastern test pit which is 30 steps east of the western test pit.

[46] Schoch, E. P., Barnes, V. E., and Parkinson, G. A., High magnesia marble from Sharp Mountain area of Llano County, Texas: Univ. Texas, Bureaus Econ. Geol., Eng. Res., Ind. Chem., Min. Res. Circ., pp. 1-2, May 10, 1938.

these marbles (C4312) is described below (LL-6).

A rather accurate transposition of the chemical composition into mineral composition can be made if the minerals which are present are known. The common minerals in these marbles are the carbonate minerals, dolomite and calcite, the silicate minerals of the actinolite-tremolite series, and diopside. The calculated mineral composition of these marbles is contained in Table 40.

Table 40. Mineral composition calculated from analyses of dolomitic marbles of Sharp Mountain area, Llano County.

	C4308	C4312	C4318	C4319	C4320	C4321	C4322
Dolomite	85.6	88.5	83.6	69.3	75.8	93.3	62.7
Calcite	5.4	4.1	9.9	7.8	8.2	3.4	9.2
Actinolite	5.4	3.6	2.2	17.0	9.9	—	15.7
Tremolite	—	2.9	—	4.2	4.8	—	11.6
Diopside	—	—	—	—	—	1.0	0.1
Siderite	2.8	—	1.1	—	—	—	0.2
Excesses	(CO_2) 0.2	—	—	(SiO_2) 0.5	—	(CaO) 0.3	—
Excesses $Fe_2O_3+Al_2O_3$	—	1.0	1.3	—	0.2	1.0	0.1
Carbonates:							
$MgCO_3$	39.1	40.4	38.2	31.6	34.6	42.6	28.7
$CaCO_3$	51.9	52.2	55.3	45.5	49.4	54.1	43.2
$FeCO_3$	2.8	—	1.1	—	—	—	0.2

In Table 40 the actual carbonate minerals present are stated with only a small margin of error. From these minerals the carbonates present are calculated and placed at the bottom of the table. If the amount of these carbonates is compared with that given in the original article, a large difference is apparent. The present method of statement is more nearly correct and comes near to the actual facts.

Description by Localities

Burnet County

LOCALITY BU-10

Location and geology.—Marble outcrops southwest of Burnet in the right-of-way of the Kingsland road, 7 miles from the railroad at Kingsland. Several marble beds up to 30 feet thick, separated by schist, are present in this area. The marble beds were traced for a distance of about half a mile eastward to Peter Creek. Along the creek highly contorted marble is exposed, and in several places sharp folds were seen. Contorted bands in the marble form raised patterns on the marble outcrops. In connection with a Work Projects Administration mineral resource survey of Burnet County, the northernmost band of marble was trenched, exposing 30 feet of steeply dipping marble in contact with granite on the north side and graphitic schist on the south side. Ten feet of the marble bed in contact with the schist is very impure, containing much vesuvianite and wollastonite.

Megascopic description.—The marble is predominantly gray and irregularly banded. Some of the bands are grayish white and others are dark gray. The marble takes a somewhat dull polish.

Microscopic description.—The marble is composed predominantly of dolomite in grains up to 1.5 mm. across and a very small amount of calcite. The average grain size is somewhat less than a millimeter. Lamellar twinning is abundant in the dolomite grains. An opaque mineral in very fine particles, probably graphite, is scattered sparingly throughout the dolomite.

Recommendations.—The marble takes a somewhat dull polish and is in rather thin beds, none of which is more than 30 feet thick. In general the color of the marble is rather somber. It is a good marble but others closer to transportation are undoubtedly better.

Llano County

LOCALITY LL-6

Location and geology.—A deposit of marble is located at the southeastern foot of Sharp Mountain 6 miles by road southeast of Llano. Several trenches and test pits were made in the marble by the United States Gypsum Company. The Dezendorf Marble Company produces terrazzo chips at this locality. The marble bed is about 200 feet thick and more than a half mile long. It is part of the Packsaddle schist series. The granite of Sharp Mountain intrudes the schist a short distance to the northwest.

Megascopic description.—The marble is predominantly white with some small areas of a very light ivory color. The rock is fine to medium grained. A sawed surface is very beautiful with each dolomite crystal reflecting light. The marble takes an excellent polish and is highly translucent.

Microscopic description.—The marble is composed predominantly of dolomite and a few grains of calcite. Tremolite is relatively abundant and a very small amount of diopside is present. The carbonate grains are relatively free of included particles. The silicates, however, are excessively clouded. Some small pyrite veinlets are exposed in the terrazzo chip quarry. A thin section shows an abnormal concentration of tremolite along the pyrite. The grain size of the marble is about 1.5 mm.

Chemical analysis.—A chemical analysis of the marble is given in Table 39, analysis C4312. This analysis cannot be considered as an average of the marble as a whole since it was taken from only one portion of the deposit. From a sight examination of the deposit, some areas are present which appear to contain much less impurities, and other areas are present in which the impurities are more abundant. The calculated mineral composition is given in Table 40.

Recommendations. — The marble is mostly of a beautiful white color, is very translucent, and is in a large deposit. It is exceptionally strong and durable and is highly desirable for an ornamental, monumental, and building stone.

LOCALITY LL–18

Location and geology.—A marble deposit is located about 2 miles southeast of Oxford along Hondo Creek. The road from the deposit to Oxford is graded but not otherwise improved and the 11 miles of road from Oxford to Llano is hard surfaced. This marble bed is one of a group mapped by Paige.[47] It is about 300 feet wide with a schist band near the middle. Some impurity in the marble discolors it at the surface. No openings have been made in the marble; consequently, the quality of the stone with depth is unknown. During 1942 a much larger, more coarsely crystalline, and better colored marble mass was seen exposed to the southwest in Hondo Creek near a coarse-grained granite contact.

Megascopic description.—The marble is somewhat banded and is of a light brown color. The bands vary in color from a clear light gray to a light cream-brown. The marble takes a good polish.

Microscopic description.—The marble is composed predominantly of dolomite bands alternating with thinner bands composed essentially of calcite and serpentine. The marble contains an occasional grain of unaltered diopside, a few partially altered diopside grains surrounded by serpentine, and some pyrite. The average size of the dolomite grains is about 1 mm. and some grains are as much as 3 mm. in size. The serpentine areas are rounded and probably average about one-fourth of a millimeter in size.

Recommendations.—A large amount of good quality marble outcrops in the area. It takes a good polish and should be of value as a building and ornamental stone.

LOCALITY LL–34

Location and geology.—A marble deposit is located 1.5 miles south-southeast of Llano and just east of Oatman Creek. The marble is not well exposed. Some steeply dipping marble beds outcropping a few inches above the surface are separated by low-lying areas in which solid surfaces of bedded marble are present. The marble is highly banded and varies widely in color. Granite outcrops a short distance both north and south of the marble.

Megascopic description.—The marble is banded with a considerable number of pastel shades making up the bands. Some of the bands are almost white and others are gray. The majority of the bands are various shades of yellowish green and very light brown. The marble takes a rather good polish even though there is considerable difference in the hardness of the minerals.

[47]Paige, Sidney, Description of the Llano and Burnet quadrangles: U.S. Geol. Survey Geol. Atlas, Llano-Burnet Folio (No. 183), 1912.

Microscopic description.—The marble is composed of dolomite, calcite, serpentine, diopside, and a very small amount of pyrite. Dolomite is the most abundant mineral, and the grains average about one-half of a millimeter in size. The diopside is present mostly as remnants surrounded by serpentine. The serpentinization has taken place around the periphery of the grains and along cleavages, producing disconnected fragments of diopside having similar orientation.

Recommendations.—The marble is of good quality, has a rather pretty, somewhat variegated color, takes a good polish, and is rather close to railroad transportation. The outcrop, however, is not well exposed and appears to be limited in size. If exploration reveals sufficient marble, it will be of value for an ornamental and building stone.

LOCALITY LL–54

Location and geology.—A marble deposit is located about 3 miles southeast of Oxford between Hondo Creek and the road to the east. The road to Oxford is graded but otherwise unimproved, and the highway from Oxford to Llano, a distance of 11 miles, is hard surfaced. The marble trends north-south and is well exposed. Part of the outcrop appears to be massive with beds and joints widely spaced. Some of the outcrop is thin bedded and stained from weathering. Pyrite is present in some of the marble, and silicates can be seen on weathered surfaces. The marble is medium to fine grained, and there is a rather large amount of it. Graphite schist borders the marble. Just to the east of the road another marble bed boldly outcrops and appears to be mostly massive marble. In his map of the area Paige[48] shows numerous north-south trending beds of marble.

Megascopic description.—The marble is more or less mottled, variegated, and has a very wide range in colors including grays, yellows, browns, and greens of many shades. The marble takes a fair polish except in some of the yellow and brown areas.

Microscopic description.—The marble is composed predominantly of dolomite and some calcite. The silicate minerals are mostly serpentine and a small amount of talc, diopside, and wollastonite. The dolomite and calcite grains range mostly between 1 and 2 mm. in size. Pyrite is present in small amounts.

Recommendations.—Marble beds are abundant in the areas east of Oxford. The marbles vary considerably in color and in their ability to take a polish. The sample collected is of a pleasing color and takes a fair polish. It is a desirable ornamental and building stone; however, it is rather far from a railroad.

LOCALITY LL–55

Location and geology.—A marble deposit is located near the north city limits of Llano and west of the Llano-San Saba highway. It is about 1 mile north of the railroad. The marble dips 55° S. 10° E. A quarry has been opened in a 15-foot bed of highly banded gray marble. The quarry is about 20 by 30 feet in size and is 10 feet deep. The marble is massive and can be quarried in large blocks. Beneath the marble is 10 feet of graphite schist, and above it is 50 feet of amphibolite followed by another thin marble bed.

Megascopic description.—The marble is irregularly banded with a nice contrast between some of the white and black bands. The majority of the bands are clear gray with a small amount of yellow-green in some of them. This is rather a brilliant stone which, however, does not take a uniform polish.

Microscopic description.—The marble is composed predominantly of dolomite and a small amount of calcite. The silicates are rather abundant and consist of diopside, serpentine, talc, and wollastonite. The diopside is slightly altered in some areas to serpentine. The dolomite grains average about 1 mm. in size and range up to about 3 mm. in size. The rock is banded with narrow bands of calcite and silicate minerals alternating with wider bands of dolomite. Pyrite is present in small amounts.

Recommendations.—The marble is a brilliant stone which does not take a uniform polish. The contrast between black and white bands in the marble is marked. The bed is rather thin to be produced, but it has one advantage in that it is near

[48] *Idem.*

a railroad. It is a desirable ornamental marble.

MAGNESITE MARBLES

Magnesite marbles were not sampled for physical testing during the building stone investigation. However, Mr. Parkinson collected a marble sample from a boulder exposed at the surface on the Stribling ranch 6 miles southeast of Llano near the southwest end of Sharp Mountain. The amount exposed was insignificant, and at the time the original sample was collected the deposit appeared to be insufficient in size to warrant investigating. Mr. Parkinson found that this rock had an excessive specific gravity, which led him to have it analysed. It contained 42.1 per cent magnesia (MgO) which indicated a high magnesite content. In the meantime, Mr. E. B. Snead opened a quarry in the deposit to obtain terrazzo chips. A chip sample was obtained from the quarry faces and other samples were obtained from near-by marble beds for analyses. These samples were analysed by the Bureau of Industrial Chemistry and the results published.[49] Analyses of marbles composed predominantly of dolomite are given in Table 39, and those composed predominantly of magnesite are given in Table 41.

Table 41. Analyses of magnesitic marble from Sharp Mountain area, Llano County; E. P. Schoch and J. E. Stullken, analysts.[50]

	C4300	C4309
MgO	42.10	33.89
CaO	3.87	13.21
Al_2O_3 and Fe_2O_3	2.49	3.10
SiO_2	0.37	0.92
CO_2	48.98	47.33
Ignition loss	1.62	2.37
Total	99.43	100.82

C4300. From Stribling property near southwestern end of Sharp Mountain, 6 miles southeast of Llano, and from just east of road.

C4309. From same locality after the E. B. Snead terrazzo chip quarry was opened; sample is chip sample of the quarry faces.

[49]Schoch, E. P., Barnes, V. E., and Parkinson, G. A. High magnesia marble from Sharp Mountain area of Llano County, Texas: Univ. Texas Bureau Econ. Geol., Eng. Res., Ind. Chem., Min. Res. Circ., 5 pp., May 10, 1938.

[50]*Idem*, p. 2.

The mineral composition of these marbles calculated from the chemical analyses is given in Table 42.

Table 42. Mineral composition calculated from analyses of magnesitic marbles from Sharp Mountain area, Llano County.

	C4300	C4309
Magnesite	81.8	51.0
Dolomite	12.8	42.7
Actinolite	------	1.8
Tremolite	0.2	------
Diopside	0.6	------
Siderite	------	0.6
Excess Fe_2O_3 and Al_2O_3	2.5	2.4
Carbonates:		
$MgCO_3$	87.8	70.5
$CaCO_3$	6.9	23.2
$FeCO_3$		0.6

Magnesite has been discovered by private enterprise in other portions of Llano County as a direct result of the information contained in the mimeographed circular cited. Chelf[51] discusses magnesite mining in Llano County, and the following extract is from his paper.

> Following an extensive drilling program in Llano County, Meramec Minerals, Inc., opened a magnesite mine on the Gray Fowler tract, 3 miles southeast of Llano and approximately west of Sharp Mountain. Core testing at this locality revealed an irregular, vertical, lenticular mass of magnesite approximately 50 by 75 feet at the surface, gradually mushrooming toward the base, and ending at a depth of about 105 feet. The high magnesia area is bounded on the north, east, and south by a siliceous dolomite and on the west by a weathered or altered diorite which has overthrust the magnesite. At present, mining is by open pit or quarry and the ore is removed with a stiff-leg derrick hoist. The mine workings are approximately 25 feet in depth, and water and caving problems are becoming increasingly difficult. The present plan is to sink a shaft near the west side of the mass in order to mine with regular underground methods.
>
> The ore is high in magnesium content and has few accessories or inclusions within the lenticular mass proper. It is bluish white to gray with brown mottled areas when fresh. Individual crystals are difficult to see with the naked eye, but a hidden saccharoidal texture develops upon exposure, and it has a decided tendency to pulverize into normal crystal size. Upon partial disintegration, lumps are sugary white and very friable. The most obvious accessories are chlorite, serpentine, pyrite, and possibly tourmaline.
>
> The Texas Mines mine, located 6 miles southeast of Llano and approximately 0.1 mile south

[51]Chelf, Carl, Magnesite mining in Llano County, Texas: Univ. Texas, Bur. Econ. Geol., Min. Res. Circ. 40, 6 pp., Dec. 10, 1941.

of Sharp Mountain, was opened in April 1941 by C. E. Heinz of Joplin, Missouri. At the present time the open pit mine has an exposed working face of approximately 175 feet, and workings are from 12 to 18 feet in depth in a mass of high-grade magnesite. The ore lies between steeply dipping beds of white and cream-colored, large crystal dolomites. The line of demarcation between magnesite and the surrounding dolomites in the mine is well defined and separated by sharp joint planes. Workings have proceeded along the strike of the magnesite stratum for 105 feet but have not extended laterally to the point of defining the total length of the deposit.

The ore is a somewhat translucent crystalline magnesite with colors ranging from bluish white to pale green. There is no tendency to disintegrate upon exposure. A possible clue to the origin of this ore through the loss of calcium from a dolomite may be indicated by a fracture pattern which has healed and left old breaks as harder material than the surrounding matrix. Random samples of this ore assayed by the operator are reported to contain as much as 97 per cent magnesium carbonate with accessory minerals such as chlorite, pyrite, pyrrhotite, serpentine, and calcite. Spectographic analyses by Dr. Gabriel[52] of the U. S. Bureau of Mines gave the following results: Mg, principal; Fe, ½%; Mn, 1/10% to 5/10%; Si, ½%; Ca, 1%; Cr, Ti, Ni, not detected.

Strata bordering the northwest edge of the mine were exposed in excavating an ore ramp. These beds, mainly graphitic schists. dip steeply to the southeast. The present workings indicate that the magnesite bed follows the same general dip of surrounding beds and therefore may contain a rather large tonnage. About 100 yards south of the magnesite mine a bed of white dolomite has been opened, and several carloads have been shipped. This dolomite is rather pure, contains a small percentage of silica, and is composed of medium-sized interlocking subhedrally developed crystals. The silica occurs as tremolite spangles or radiating crystal growths. An estimated 5000 tons of low-grade magnesite lies slightly northeast of the magnesite mine, and another area approximately 100 yards southeast of the mine has an unknown quantity of high-grade magnesite. Magnesite was mined for terrazzo chips from a quarry[53] on the north side of the main Sharp Mountain road about 150 yards from the point where Texas Mines road leads to the primary magnesite mine. This magnesite is also being utilized. Although this quarry is in the same trend as the original Texas Mines mine, the magnesite tends to grade from relatively pure magnesite at the surface to a higher calcium content material as depth increases. In general, the reverse has been true of Texas Mines mine.

In April 1941 McCammon[54] located a small magnesite deposit northwest of Mason. Samples from this deposit had been seen by Parkinson and Barnes during 1938, but the whereabouts of the deposit were not revealed until later. McCammon states:

> On the outcrop, this deposit of magnesite has a maximum length of 100 feet and is 50 feet in width. Since the surrounding chloritic schist is almost standing on end, one may expect a maximum thickness of approximately 50 feet. No greater surficial width or length can be expected, for a continuous trenching around the greatest perimeter gave the length and width as already stated. Test pits dug at right angles to the strike of the outcrop failed to reveal any soil-covered bodies of ore, either on the flanks or in the continuation of the strike of the deposit. The test pits were bottomed in Packsaddle schist in every case except one. Along the northern prolongation of the strike of the magnesite a small lens of calcium carbonate marble was uncovered. . . .

It is possible that other deposits of magnesite, with or without dolomite, do occur in the extensive outcrops of Packsaddle schist in this county. As shown on the map of the magnesite [fig. 12], a long band of marble outcrops 350 yards to the east of the magnesite. This marble is almost entirely lime with very little dolomite present.

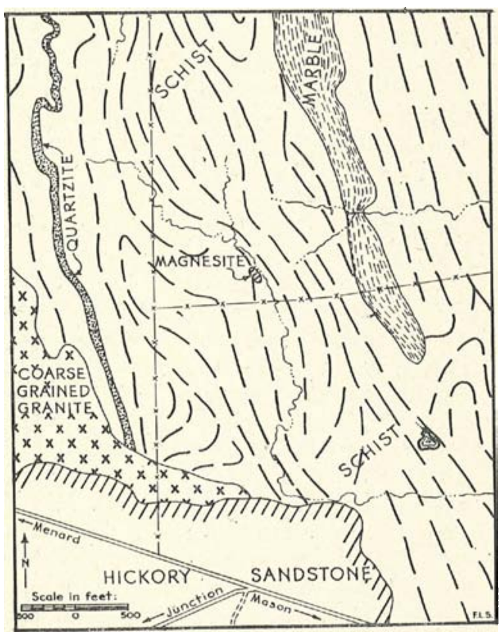

Fig. 12. Geologic map of magnesite area, 3 miles northwest of Mason, Mason County, Texas.

A chip sample of the magnesite deposit collected by the writer was analysed by W. A. Cunningham, of the Bureau of Industrial Chemistry of The University of Texas, and the results are given in Table 43, which also includes the mineral com-

[52]Personal communication to C. E. Heinz.

[53]This quarry is the original discovery site mentioned above, the E. B. Snead quarry.

[54]McCammon, J. H., Report on tin and magnesite deposits in Mason County, Texas: Univ. Texas, Bur. Econ. Geol., Min. Res. Circ. 32, pp. 4-5, July, 1941.

position calculated from the chemical analysis.

Table 43. Mason County magnesitic marble.

Chemical analysis	Per cent	Mineral composition	Per cent
Insoluble in hydrochloric acid	9.39	Dolomite	72.50
Alumina and iron oxide	0.38	Magnesite	17.72
Magnesium oxide	24.19	Silicate minerals	9.39
Calcium oxide	22.08	Excess	0.38
Ignition loss	43.96		

As already mentioned, magnesite, even though it is a beautiful white to pale green marble, will probably be used mostly for other purposes than for building stone. Several carloads have already been used for terrazzo chips, and this use may continue. Magnesite is chiefly used in producing refractories and for caustic-calcined magnesite used for building purposes. Magnesite may be of some use for drilling mud.

WOLLASTONITE MARBLES

Resumé.—Marbles of this type are not as widely distributed in central Texas as are the calcite and dolomite marbles. These marbles are evidently the result of contact metamorphism with the introduction of additional material from without the calcareous beds and the elimination of carbon dioxide from within. Both deposits sampled contain a small amount of calcite. One contained some diopside and feldspar, while the other contained vesuvianite and a small amount of quartz.

Wollastonite marbles are very tough, caused by the matted interlaced wollastonite fibers. Quarrying of these marbles would require a special technique since there is no grain or alignment direction to aid in producing breaks. Quarry methods probably would be limited to wire sawing or channeling around blocks plus undercutting to free the blocks. The toughness of this stone and its beauty and chemical stability should make it of great value where large slabs of marble are used, such as in soda fountains. The additional cost to produce these wollastonite marbles might be offset by decreased breakage.

Description by Localities

Llano County

LOCALITY LL–48

Location and geology.—A wollastonite deposit is located about one-half mile north of the Llano-Cherry Spring road at a point 11 miles from Llano. The road to Llano is graded but not otherwise improved. The wollastonite marble was probably originally an impure limestone which has been metamorphosed and changed chiefly to a calcium silicate rock. This bed or a similar one continues south of the Llano-Cherry Spring road and crosses Blount Mountain.

The wollastonite has much vesuvianite in it as rows of individual crystals and as bands of crystals in places as much as 1 foot thick. The marble is contorted and these contortions can be traced by the vesuvianite crystal bands. The vesuvianite bands apparently are localized in the marble wherever impurities of the right type existed in the marble to allow their formation. The vesuvianite is more resistant to erosion than the wollastonite and consequently weathers in relief. A few garnets are present in the wollastonite near its southern border which at this point is in contact with a pencil gneiss. Much pegmatitic and aplitic material was injected into the marble, and it would be necessary to prospect carefully for areas free of these intrusions before establishing a quarry. A small vein of opal-like material is associated with the vesuvianite in one outcrop.

Megascopic description.—The wollastonite marble is white with areas of brownish-green vesuvianite scattered through it. The wollastonite has a silky, felted appearance produced by the fiber arrangement. The vesuvianite areas vary from a quarter of an inch to several inches in size, making the rock unusually attractive. It takes a uniform but not brilliant polish. A photograph of a polished surface is shown in Plate 5.

Microscopic description.—The rock is composed predominantly of wollastonite and vesuvianite. The vesuvianite is in rounded to elongated areas up to 2 or 3 inches in size and is surrounded by wollastonite. The vesuvianite in many of these areas has the same orientation throughout. Included within the vesuvianite is some calcite and a very small amount of quartz. Needles of wollastonite are in radiate fibrous interlocking aggregates averaging about one-quarter of an inch in size. The wollastonite portion of the rock is practically free of other minerals.

Recommendations.—The wollastonite marble is extremely tough and durable. It would be difficult to quarry, and considerable prospecting would have to be done to locate areas of it free from cross-cutting intrusions. It is very attractive and is of value as an ornamental stone.

LOCALITY LL-50

Location and geology.—Wollastonite deposits are marginal to the Granite Mountain granite mass about 2.5 miles south of Kingsland. One small inclusion exposed in the road is about 20 feet wide and 200 feet long. A much larger mass of wollastonite is exposed to the east along the margin of the granite. The granite probably altered an impure marble into a wollastonite rock.

Megascopic description.—The marble is mottled with very light greenish spots irregularly distributed in a mass of white wollastonite. The wollastonite is not as felted appearing as in the last described sample. Innumerable pin point-sized bright reflections make this a very attractive marble, even though it does not take a high polish. A photograph of a polished surface is shown in Plate 5.

Microscopic description.—The rock is composed predominantly of wollastonite and diopside. Plagioclase feldspar is rather abundant and is of oligoclase composition. A small amount of calcite is present. The minerals are in general in rather small fragments of heterogeneous orientation. Some of the diopside crystals are 3 or 4 mm. in size, and all are extensively altered. In many, only disconnected fragments of similarly oriented diopside remain. Much of the feldspar contains inclusions of diopside and wollastonite. The minerals are well knitted together, and this should be a very tough and enduring building stone.

Recommendations. — The wollastonite marble is extremely tough and durable. Quarrying it would be expensive, but this might be offset by decreased breakage. It is very attractive and is of value as an ornamental stone.

SERPENTINE MARBLES[54a]

Resumé.—Six deposits of serpentine were examined. By far the largest deposit is located in Blanco and Gillespie counties, a map of which is shown in figure 11. These deposits are composed predominantly of the mineral serpentine, with occasionally other minerals such as magnetite, talc, chlorite, and tremolite. The mineral composition of the serpentines is reviewed in Table 44.

Table 44. Mineral composition of central Texas pre-Cambrian serpentine marbles.

Sample No.	Serpentine	Magnetite	Talc	Chlorite	Tremolite
Bl-14	x				
G-5	x				
G-7	x		x	x	
G-8	x	x			
Ll-2	x	x	x		x
Ll-19	x	x			
Ll-46	x	x	x		

The following paragraphs are modified excerpts from Mineral Resource Circular No. 14, pertaining to the serpentine mass in Gillespie and Blanco counties.[55]

The largest serpentine mass of the Central Mineral region of Texas is located in northeastern Gillespie County and northwestern Blanco County about 1.5 miles south of the Llano County line. The western end of the serpentine mass is about 25.5 miles from Llano by road, 20 miles of which is hard surfaced, and about 24.5 miles from Fredericksburg, 19 miles of which is hard surfaced. The eastern end of the mass is about 24 miles from Marble Falls by road, which is unimproved, and about 30 miles from Fredericksburg by road, 12 miles of which is hard surfaced. These towns are the nearest railroad points to this serpentine mass with the exception of Kingsland which is north of Llano River, which at this point is not bridged. The presence of this mass of pre-Cambrian serpentine and the occurrence of chromite and asbestos in it have been known for many years. The desirability of the serpentine as a building stone has become apparent within the past few years.

The serpentine mass is about 21 miles airline from the Lower Colorado River Authority's Buchanan and Inks dams on Colorado River which are now producing cheap power. At

[54a]Since this section was written, much of the serpentine of the Central Mineral region has been mapped. See Barnes, V. E., Soapstone and serpentine in the Central Mineral region of Texas: Univ. Texas Pub. 4301, pp. 55-91, 1943 [May, 1945].

[55]Barnes, V. E., Serpentine and associated minerals of Gillespie and Blanco counties, Texas: Univ. Texas, Bur. Econ. Geol., Min. Res. Circ. 14, 5 pp., 1940.

present, however, no power line is closer than 5 miles to the serpentine.

The writer, from September, 1939, to May, 1940, has been mapping the geology of Gillespie County, using aerial photographs as a base. A sufficient overlap of the Gillespie County photographs into Blanco County has permitted mapping of the entire serpentine mass in these two counties.

The serpentine mass [fig. 11] is 3.5 miles long in an east-west direction and averages about two-thirds of a mile across in a north-south direction. At each end of the mass there are important lobes of serpentine extending northward. Faulting has offset the borders of the mass to some extent. The faulting is probably of the same age as that which dropped the Paleozoic rocks against the pre-Cambrian rocks at the western edge of the map. The serpentine mass pitches to the south at an angle of approximately 45 degrees. The serpentine probably originated by alteration of a basic intrusion. No recognizable remnants of the original rock are found within the serpentine mass. Some hornblendites along the northern border of the mass may be related to the original intrusion. The original igneous rock from which the serpentine formed intruded a series of pre-Cambrian gray gneisses and Packsaddle schists.

Chromite was seen at three localities in the serpentine mass [fig. 11]. The largest amount of chromite present, amounting to about a ton, is shown as the westernmost occurrence on the map. The chromite is scattered over the surface around several shallow prospect holes. No chromite was seen in place. To the east, three-quarters of a mile, about 200 pounds of chromite is scattered about the surface. At the third locality another quarter of a mile eastward about half a ton of chromite is scattered about the surface. No chromite was seen in place. A few stringers of magnetite, however, were seen cutting through the serpentine at this locality.

Magnetite is abundant as small grains scattered throughout the serpentine. Stringers of magnetite were noted in the serpentine near the chromite locality on the Gould Davis ranch. A prospect hole along the northern margin of the serpentine reveals 21 inches of magnetite in a schistose rock within a few feet of the serpentine and apparently parallel to it. The length of the magnetite stringer has not been determined.

A shallow prospect hole [fig. 11], mostly within an inclusion in the serpentine reveals the presence of the secondary nickel mineral zaratite. Along the entire northeast-trending edge of the serpentine mass near this locality there is a zone of honeycombed, somewhat iron-stained quartz.

Talc schist is present at many places around the periphery of the serpentine mass and is also found as inclusions within the serpentine. Most of the talc schist appears to be a mixture of talc with other silicate minerals and is properly classified as soapstone. The soapstone has been used locally for hearthstones and chimneys and stands heat changes without deterioration.

The serpentine mass contains a wide assortment of shades of green ranging from light yellowish greens through deep greens to very dark rocks having a greenish cast. Two terrazzo chip quarries have been opened in the western end of the serpentine mass. Serpentine from a mass in Llano County has been used to surface newly constructed highways of that area. The serpentine produces an excellent non-skid driving surface, having a minimum of glare, thus reducing eye strain during the day and yet is light enough in color to furnish a nicely visible surface for night driving.

In general the serpentine mass is much jointed which reduces the amount of stone that can be produced for saw blocks. With careful selection of quarry sites it should be possible, however, to produce large-sized blocks for sawing.

A small amount of asbestos is present in the serpentine usually associated with inclusions of schist. A prospect hole in the eastern part of the serpentine mass reveals some asbestos.

After Mineral Resource Circular No. 14 was issued, some of the asbestos of this area was examined microscopically. The asbestos from the above-mentioned prospect hole had a refractive index near that of tremolite but so far as could be determined had parallel extinction. Dr. Duncan McConnell obtained an X-ray pattern of this material which in part checked tremolite but which contained additional lines, indicating that the sample is a mineral mixture.

A sample of asbestos present as one-quarter to one-half inch veins in serpentine, taken from a site a few hundred yards to the northwest of this locality, has a refractive index slightly higher than that for ordinary chrysotile. This sample, however, gives a good chrysotile X-ray pattern.

Description by Localities

Blanco County

LOCALITY BL–14

Location and geology.—A serpentine sample was collected from the eastern end of the large serpentine mass of Blanco and Gillespie counties, just described.

Megascopic description.—The sample of serpentine collected is only one type of several present in the area. It is light to medium dark green in color and has numerous light-colored, fibrous aggregates in it. These aggregates have a random orientation and are up to one-half of an inch in length. The serpentine does not polish well; a sawed surface, however, is attractive.

Recommendations.—The serpentine mass is extremely large but is rather far from a railroad. The serpentine varies considerably in color and is an attractive stone even though it does not take a good polish. The serpentine should be of value for an ornamental stone, for terrazzo chips, and possibly for the production of magnesium.

Gillespie County

LOCALITY G-5

Location and geology.—A very small deposit of serpentine on the Althaus ranch is located just east of Youngblood Creek, about one-half mile west of the Willow City-Round Mountain road. It is about 23 miles from Fredericksburg by road, 12 miles of which is hard surfaced.

Megascopic description.—The serpentine, in color, is a combination of light greenish white and very dark greenish black arranged in a semi-dendritic manner. A small amount of intermediate green serpentine is mostly concentrated near veinlets in the serpentine. A dark brown limonitic material is also associated with the veinlets and to a small degree is scattered throughout the rock. A sawed surface of this rock developed a higher lustre than did one which was polished.

Microscopic description.—The serpentine was not examined in thin section. A powdered sample consisted of serpentine aggregates and fibrous aggregates having an index of refraction for N′g near 1.579. A colorless mineral present in small amounts has a slightly lower index of refraction. The serpentine is composed of serpentine minerals, and the fibrous material is probably chrysotile having an abnormally high index of refraction.

Recommendations.—The serpentine deposit is extremely small. The serpentine is attractive and would be of value as an ornamental stone if sufficient quantity is present to be quarried.

LOCALITY G-7

Location and geology.—A deposit of serpentine is located in northeastern Gillespie County between Coal Creek and the Willow City-Cut Off Gap road. It is about one-half mile south of the western end of the large serpentine mass (fig. 11) of Gillespie and Blanco counties. The serpentine forms a small rounded knob and is darker in color than most of the serpentine of the area. Considerable talc and some chlorite are present. Serpentinization is not complete.

Megascopic description.—The serpentine is composed of alternate bands of very dark green and very light green which have a marked contrast. The serpentine takes a rather dull polish.

Microscopic description. — Alternate laminae of light green and dark green serpentine comprise the rock. The dark green laminae are composed chiefly of network serpentine and a small amount of talc. One crystal within the dark green serpentine contains Schiller inclusions and resembles enstatite or clinoenstatite somewhat altered to bastite. Network serpentine has embayed the edge of the crystal and included some of the Schiller inclusions. Another area of similar Schiller inclusions has only a small amount of the original mineral present as laths having various orientations interleaved with talc, indicating that the mineral is altering to talc. Most of the Schiller inclusions are surrounded by talc and serpentine. The lighter colored areas are composed predominantly of talc, with some serpentine, and a small amount of chlorite. In both the light and dark-colored laminae, small elongated areas of opaque minerals are present in the same abundance, indicating that the rock may have been originally of uniform composition throughout.

Recommendations.—The deposit is rather small and the physical properties have not been determined. It is probably of good grade even though limited in amount.

LOCALITY G-8

Location and geology.—A sample was collected from the western end of the large serpentine mass of Gillespie and Blanco counties previously described. Three terrazzo chip quarries are located in serpentine in this area (fig. 11). Much of the serpentine exposed in the quarries is slickensided and unsuited for producing dimension stone.

Megascopic description.—The serpentine is a somewhat irregularly colored stone with colors ranging from a light greenish white to a deep greenish black.

The light greenish-white serpentine has a semi-dendritic pattern with a background of olive-green. It is somewhat veined by narrow white veins which to some extent are stained a limonitic brown. The limonitic brown color also penetrates the rock for a short distance along some of the veins. The serpentine takes a dull polish.

Microscopic description.—The serpentine is composed predominantly of net-structured serpentine, magnetite, and a small amount of a fibrous mineral which may be a remnant of the original mineral. In addition to the primary magnetite grains, considerable finely divided secondary magnetite is concentrated in some of the serpentine.

Chemical analysis.—An analysis of the serpentine and the approximate mineral composition calculated from the analysis are given in Table 45.

Table 45. Serpentine from along Coal Creek.

Chemical analysis*	Per cent	Mineral composition	Per cent
SiO_2	40.31	Serpentine	93.19
Al_2O_3	0.43	Magnetite	1.39
Fe_2O_3	6.71	Chromite	0.67
FeO	0.70	Pyrite	0.06
MgO	37.63	Calcite	0.14
CaO	0.05	Opal	4.72
Na_2O	0.01		
K_2O	0.00		
H_2O+	12.32		
H_2O-	0.92		
CO_2	0.06		
TiO_2	0.01		
P_2O_5	0.01		
Cr_2O_3	0.41		
MnO	0.04		
BaO	0.00		
NiO	0.30		
F	0.01		
S	0.03		
	99.95		
Less O	0.02		
	99.93		

*Analysed at the Minnesota Rock Analyses Laboratory, Minneapolis. Analyst: R. B. Ellestad. Fluorine determination by Willard and Winter method.

This rock is composed predominantly of serpentine which may be calculated into the following serpentine molecules:

	Per cent
$H_4Ni_3Si_2O_9$	0.54
$H_4Mg_2Al_2SiO_9$	1.19
$H_4Mg_2Fe_2SiO_9$	12.98
$H_4Mg_3Si_2O_9$	85.29

Recommendations. — A very large amount of serpentine is available in the deposit. Even though much of the serpentine exposed in the quarries is slickensided, undoubtedly areas are present in which large sound blocks can be quarried. The serpentine is used for terrazzo chips. It may also be of value for granules in highway construction and can possibly be used for the production of magnesium.

Llano County

LOCALITY LL–2

Location and geology.—A small serpentine mass is located 3 miles east of Enchanted Rock just north of the Enchanted Rock–Llano road, 5.7 miles west of the Llano-Fredericksburg highway at a point 15 miles south of Llano. The road is graded but not otherwise improved. A low ridge of serpentine and other rocks trends in an east-west direction. Pits dug on the ridge expose serpentine, anthophyllite asbestos, vermiculite, and several other metamorphic minerals. The value of the serpentine as a building stone is questionable.

Megascopic description.—The serpentine is somewhat mottled and is composed of dirty white, grayish-white, and greenish-black areas. The grayish-white color forms a rather broken background for the other colors. Narrow green veins having little contrast with the rest of the rock are present but are not numerous. The serpentine takes a dull polish.

Microscopic description.—The serpentine is composed predominantly of net-structured serpentine, considerable talc, and a small amount of tremolite and magnetite. The magnetite is present both as primary grains and as finely divided secondary material mostly present at grain boundaries of the serpentine. Many of the serpentine grains are very light yellowish brown at the edges with a marked increase of color intensity at the centers. The serpentine grains are uniformly small and average about one-fourth of a millimeter in size.

Recommendations.—The quality of the serpentine is too poor and the quantity is insufficient to justify establishing a quarry for its production.

LOCALITY LL-19

Location and geology.—A serpentine mass is located on a high hill a short distance west of the Llano-Fredericksburg highway at a point about 8.5 miles south of Llano. The serpentine mass which is 100 to 125 feet wide trends in a north-south direction. Several test pits have been made in the serpentine, and recently a road material pit was opened in it from which granules were taken for surfacing the Llano-Fredericksburg highway and the lake shore drive of eastern Llano County. Some talc and vermiculite are adjacent to the serpentine.

Megascopic description.—The serpentine has a rather uniform medium green color and contains a few narrow disconnected white veinlets and many small black areas of magnetite. The serpentine takes a dull polish.

Microscopic description.—The serpentine is composed predominantly of serpentine and a rather large amount of magnetite. The serpentine varies considerably in structure and optical properties, suggesting that it has formed from more than one mineral. Several blades of serpentine up to 1 cm. in length have a higher and more variable birefringence than does most of the serpentine. This mineral appears to have been originally one of the amphiboles. Some areas of magnetite arranged in the manner of Schiller inclusions suggests that enstatite or hypersthene may have also been one of the original minerals. Much of the serpentine has a net structure which gives very little indication of the original mineral. Much of the magnetite of the serpentine is in grains, and the rest is in a form suggestive of Schiller structure. No secondary magnetite produced during serpentinization was seen.

Recommendations.—The deposit of serpentine is not large, but it is probably of good grade since it passed rather rigorous road material tests and has been extensively used on the highways in Llano County. The serpentine is rather highly jointed, and it may be difficult to find an area in which large blocks can be quarried. The serpentine is of value for terrazzo chips and granules.

LOCALITY LL-46

Location and geology.—Serpentine is located on a high hill just west of the hard-surfaced Llano-Fredericksburg highway at a point about 8 miles south of Llano. Just to the east of the serpentine a 30-foot test pit has encountered talc and related minerals including vermiculite. The serpentine is essentially the same as that described under Ll-19.

Megascopic description.—This sample of serpentine is the lightest colored of those examined. The color is grayish green but some areas apparently localized along joints are of much lighter color. Small black grains of magnetite are rather sparsely distributed throughout the rock. The serpentine takes a dull polish.

Microscopic description.—The serpentine is composed predominantly of serpentine minerals. A small amount of talc is present, most of which has a shredded appearance with serpentine developing around the edges and along the cleavages. The serpentine in many of these areas is stained by a limonitic appearing material. Magnetite is rather abundant mostly as original grains, some of which have been broken, with serpentine penetrating the cracks. Only a very small amount of secondary magnetite is present. The serpentine is of a network type and does not give much indication of the original mineral from which it was formed.

Recommendations.—The same recommendations are made for this serpentine as for that described under Ll-19.

SOAPSTONE

Properties and Uses

Soapstone is used in limited quantities for a building material. Because of its physical properties, resistance to weathering, chemical stability, workability, and light color, it is admirably fitted for making laundry tubs, sinks, aquariums, wainscoting, mantels, baseboards, stair treads, tiles, spandrels, laboratory table tops and sinks, hoods, ovens, acid tanks, vats, trays, development tanks for photographs and blue prints, drains, and furnace blocks. Some soapstones are desirable for electrical insulation units such as switchboards, panels, barriers, fuse guards, fuses, circuit-breaker compartments, insulating floor slabs, battery-room flooring or shelving, and similar products. Soapstone resists and retains heat to a high degree and for this reason is used for griddles, foot warmers, fireless cooker stones, and for linings of fireplaces, hearths, and furnaces.

The soapstone of this region has been used mostly for fireplace and hearth linings with very satisfactory results. A use not noted above which was common in this area before the introduction of modern gates is the use of soapstone as bearing blocks for gates.

In addition to the above uses of soapstone for fabricated products, it is ground for a variety of uses. The Bureau of Mines[56] lists the following uses for ground talc, pyrophyllite, and soapstone.

Talc serves the paint industry principally as an extender, although in some paints it is the principal pigment. The fibrous talc (asbestine), a mixture of tremolite fibers and talc, is used largely in cold-water paint, the fibers of tremolite bonding the paint film. Flake talc and pyrophyllite are also incorporated in paints.

White fine-grained talcs are used for loading the better grades of paper. The low-priced, off-color, low-grade talcs and pyrophyllite are used to form an inert, fire-proof, weather-resisting coating for roofing papers.

Talc and pyrophyllite enter the ceramic industry in considerable quantities. Calcined talc ("lava") meets the special requirements of the electrical and refractory industries, being sold either as calcined sawed and machined block material or compounded from talc and silicate of soda and then pressed into blocks and calcined. An important use of talc in the ceramic industry is in the preparation of sagger bodies. Considerable quantities of talc are sold to wall-tile and whiteware manufacturers, who also utilized pyrophyllite.

Various industries needing fillers utilize talc, pyrophyllite, and ground soapstone. Rubber manufacturers are said to take the largest amounts for use either as a filler or as a lubricant. Smaller quantities are used by the makers of asbestos goods, floorings, wall plasters, insecticides, ropes, and plastics.

The lubricating properties of talc, pyrophyllite, and ground soapstone are utilized in many industries. Manufacturers of cup greases, foundry castings, rubber tires, bottles, and candy and users of box-nailing machinery and dies of various kinds consume small quantities.

Talc is the principal base in various toilet preparations, but this use is very small compared with total talc consumption. Some pyrophyllite has been used. Fine, pure-white material is required for this use.

Talc is used for abrasive or polishing purposes where the material to be polished is soft, such as peanuts or coffee beans, or where the dirt is to be removed from a soft underlying material, such as marble or lacquer.

The soapstone of central Texas will meet the requirements for many of the above uses. However, insufficient testing has been done to outline the uses for which it is especially suited. From a microscopic examination of the soapstone, it is seen that there is a wide variation in mineral composition and consequently there will be a wide variation in physical properties. An industry based on soapstone in this area would have a wide range of choice in raw materials.

Central Texas Pre-Cambrian Soapstones[56a]

Resumé.—Soapstone is abundant in an area of northeastern Gillespie County and northwestern Blanco County. During the present investigation a deposit in Llano County and one in Mason County were also sampled. Under the heading "talc," Paige[57] states: "In the area immediately east of Cedar Mountain numerous small outcrops were seen, though no deposit was mapped separately. A small deposit also occurs 1½ miles west of Llano, and one upon which considerable work has been done is located a mile north of Graphite station." In reference to the latter deposit, Paige states: ". . . it is probable that the mass of soapstone is at least 20 feet wide, 90 feet long, and 25 feet thick." The deposit west of Llano and the one north of Graphite could not be found while investigations were being made of the soapstones of the region during the spring of 1943.

In reference to the soapstone east of Cedar Mountain, Paige states: "The talc in this area is probably in large measure derived from limestones by the hydration of magnesian silicates. It is almost certain, however, that some of the deposits are due to the alteration of basic intrusives or their equivalents, the amphibole schists."

[56] Johnson, B. L., Marketing talc, pyrophyllite and ground soapstone: U.S. Bur. Mines, Inf. Circ. 7080, pp. 2—3, 1939.

[56a] Since this section was written, the soapstones of the Llano area have been mapped. See Barnes, V. E., Soapstone and serpentine in the Central Mineral region of Texas: Univ. Texas Pub. 4301, pp. 55–91, 1943 [May, 1945].

[57] Paige, Sidney, Description of the Llano and Burnet quadrangles: U.S. Geol. Survey Geol. Atlas, Llano-Burnet Folio (No. 183), p. 14, 1912.

Other deposits which he described are attributed to the hydration of magnesian silicates developed by regional or contact metamorphism in pre-Cambrian limestone.

At the edges of the large serpentine mass in Blanco and Gillespie counties, and associated with amphibolite as inclusions in the serpentine, are many small deposits of soapstone. However, the presence of soapstone in these positions does not mean that the soapstone is derived from the serpentine or its parent rock. In this case it seems fairly evident that the intrusion followed a belt of Packsaddle schist which contained abundant soapstone. All of the other soapstone deposits seen in this area are associated with Packsaddle schist which is included in gray quartz-diorite gneiss. The origin of the soapstone has not been determined. From its association with amphibolites and schists of sedimentary origin, it is likely to have been derived from impure marbles.

Description by Localities

Blanco County

LOCALITY BL–10

Location and geology.—A soapstone sample was collected from a 1500-foot outcrop which is located about three-quarters of a mile southeast of the northwestern corner of Blanco County. It outcrops as a crescent about the northernmost point of the serpentine mass and at a distance of a few hundred feet from it (fig. 11). To the south and east of the soapstone are several other soapstone outcrops, some of which flank the serpentine mass. The soapstone is about 10 miles by road east of the Llano-Fredericksburg highway at a point about 20 miles south of Llano. The first 5 miles of the road is very rough and the next 5 miles is little better.

Megascopic description.—The soapstone is greenish gray and of a uniform fine-grained texture. Magnetite as small grains is very sparsely distributed throughout.

Microscopic description.—The soapstone is composed predominantly of talc, tremolite, and a very minor amount of magnetite. The talc has a scaly to plumose appearance. Basal plates give an essentially uniaxial interference figure, probably due to superposition of laminae having varied orientations. The tremolite is present mostly as sheaf-like aggregates, many of which are interrupted by talc scales.

Recommendations.—A rather large amount of soapstone is present in this outcrop and in others to the southeast. It appears to be of good grade. Some magnetite is present which might be objectionable if the soapstone were to be ground, but the magnetite could be easily removed by a magnetic separator.

LOCALITY BL–23

Location and geology.—A soapstone deposit, located just north of the large serpentine mass of Blanco and Gillespie counties near the Gillespie County line, is about 10 miles by road east of the hard-surfaced Fredericksburg-Llano highway at a point 20 miles south of Llano. The first 5 miles of the road is very rough and the next 5 miles is only slightly better. Several other soapstone outcrops are present, some of which are to the west in Gillespie County. These soapstone outcrops are shown in figure 11. A small amount of soapstone has been quarried for local use. The soapstone is grayish green, and boulders of it lie about the ground. The soapstone masses are associated with amphibolites and schists.

Megascopic description.—The soapstone is mostly deep grayish green but some areas are somewhat lighter in color. The lighter colored areas are finely granular, whereas the darker areas are composed of crystalline aggregates mostly less than a quarter of an inch in size. The soapstone does not take a polish. The fibrous aggregates have a sheen.

Microscopic description.—The soapstone was not examined in thin section. A powdered sample is composed essentially of talc and a small amount of chlorite. Magnetite is present in minor amounts.

Recommendations.—A number of soapstone deposits, none of which is large, are located in this area. The soapstone appears to be of good grade.

LOCALITY BL–24

Location and geology.—A soapstone mass located just east of Comanche Creek forms a small but prominent hill. It is 1 mile north of the old Blowout post office and is about one-half mile west of the Willow City-Round Mountain road. It is about 27 miles from Fredericksburg by road, 12 miles of which is hard surfaced. An old quarry is located on the western side of the soapstone mass from which soapstone for local use has been obtained. It is grayish green in color. The soapstone mass is about 500 feet long by about 50 feet thick and is part of a large schist mass included in a gray gneiss. Across Comanche Creek and one-quarter of a mile distant is another band of amphibolite which contains soapstone.

Microscopic description.—The soapstone is composed predominantly of talc, chlorite, and tremolite. Talc is by far the most abundant mineral and is present as leafy scales arranged at random and overlapping to such an extent in thin section that the optical properties are difficult to determine. The chlorite is of negative optical character, has a mean index of refraction of about 1.595, and is, therefore, delessite. Tremolite is the least abundant mineral of the three and is arranged in sheaves. These minerals vary in relative abundance throughout the rock. Magnetite is present in very small amounts. A finely devided mineral resembling apatite is present chiefly in the chlorite.

Recommendations.—Considerable soapstone is present in this mass and in masses to the west. It appears to be of good quality and is of value for ground soapstone and possibly for fabricated products.

Gillespie County

LOCALITY G–1

Location and geology.—A soapstone deposit located on the Llano County line and on the west bank of Crabapple Creek is about three-quarters of a mile south of the Enchanted Rock road. The nearest railroad is at Llano, a distance of 21 miles by road, 15 miles of which is hard surfaced and the rest of which is mostly graded. The soapstone is in several small masses extending from near Crabapple Creek in Gillespie County along a ridge in a direction N. 55° W. for a distance of about one-quarter of a mile into Llano County. Amphibolite and mica schist are parallel to the soapstone and dip 45 degrees to the southwest.

Megascopic description.—Talc, chlorite, tremolite, vermiculite, and other platy and fibrous minerals are abundant. The color of the soapstone varies through a wide range of greens and gray-greens.

Recommendations. — The soapstone masses are small and little of it is of good grade. This deposit is probably of little value.

LOCALITIES G–4 AND G–6

Location and geology.—Many small soapstone deposits are located west of the Willow City-Round Mountain road in eastern Gillespie County near the Blanco County line. The area is about 24 miles by road from Fredericksburg.

During the summer of 1942, R. W. Mathis mapped most of the soapstone area in detail, but the map was not completed in time to be included in this publication. Hundreds of small soapstone pods were mapped in an area about 2.5 miles long and about one-quarter of a mile wide, extending from the Willow City-Round Mountain road northward parallel and to the west of Big Branch. The soapstone is on the W. O. Davis, A. Davis, and Althaus properties. Sample G–4 was collected from the A. Davis property in the first drain to the east of the road leading to the A. Davis barite prospect. Sample G–6 was collected just west of the Willow City-Round Mountain road a short distance below the Althaus residence.

The soapstone is associated mostly with schists and some amphibolite and serpentine. The soapstone, schist, and amphibolite have been included in a large mass of quartz-diorite gneiss. Much of the soapstone on the Althaus property and part of that on the A. Davis property is gritty and of sub-standard grade. The larger and more uniform deposits are located on the W. O. Davis property to the north. The soapstone is resistant to weathering and mostly forms ridges which shed blocks of soapstone down the slopes.

The estimated tonnage of soapstone in the area mapped is 660,000 tons.

Megascopic description.—Sample G–4 is grayish green and is composed of fibrous radiate and sheaf-like to feathery aggregates having random orientation. Some of these aggregates are an inch or more in length. This rock takes a dull polish, but the fibers have a silky sheen which produces an attractive appearance.

Sample G–6 is composed of abundant greenish-white radiate-fibrous aggregates, separated by dark green areas. It does not take a polish and the fibrous aggregates have very little sheen.

Microscopic description.—Sample G–4 was not examined in thin section. A powdered sample is composed mostly of tremolite and a small amount of chlorite. A powdered sample of G–6 is composed mostly of tremolite and talc. Many small, very thin, semi-translucent plates having six sides included in the talc and tremolite may be ilmenite.

Recommendations.—A large amount of soapstone is contained in the numerous pods in the area mapped. The soapstone varies considerably in its mineral composition throughout the area but should be of value for numerous sawed and carved articles and as a ground product for numerous uses.

Llano County

LOCALITY LL–10

Location and geology.—A soapstone deposit located just west of the road leading from Sandy Creek to Kingsland is about 4.5 miles south of Kingsland. The road to Kingsland is only slightly improved, and there is no bridge over Llano River. The deposit is about 19.5 miles from Marble Falls and about 24.5 miles from Llano by graded roads. The soapstone is probably a portion of one of the numerous impure marble beds in the area altered by some near-by intrusive. A marble (Ll–8) from this vicinity is described on page 96.

Megascopic description.—The soapstone is light buff with some glitter from the talc scales. It is evenly granular in appearance and does not take a polish.

Microscopic description.—The soapstone was not thin sectioned. A powdered sample shows it to be composed predominantly of talc. A small amount of quartz and tourmaline is present—sufficient to cause a distinct gritty sound when the powder is rubbed between two glass plates.

Recommendations.—The soapstone contains grit and is not pleasing in color. The amount present is unknown. It is probably of little value.

Mason County

LOCALITY M–18

Location and geology.—A deposit of soapstone located about 75 yards west of the Fredonia-Brady road north of Fredonia is about 23 miles from the nearest railroad, which is at Brady. Two deposits of the soapstone outcrop on the Bratton ranch, one about one-half mile north of the ranch house and the other near the Fredonia-Brady road. The soapstone is poorly exposed, and estimates of the quantity present cannot be made without some exploratory work. It has been used locally for lining hearths.

Megascopic description.—The soapstone is dark grayish green mottled by buff. The buff areas are rough triaxial ellipsoidal in shape; thus the pattern obtained depends upon the direction in which the stone is cut.

Microscopic description.—The soapstone was not thin sectioned. A powdered sample reveals tremolite, talc, and chlorite to be the predominant minerals.

Recommendations.—The soapstone is poorly exposed, and little is known about the amount present or the quality. This deposit is probably of little value.

AMPHIBOLITE AND EPIDOTE ROCK

Amphibolites in some areas of the central Texas pre-Cambrian are fairly massive in outcrop and would probably be quite massive with depth. The amphibolites were not examined except for two areas in Llano County, one in Mason County, and one in Burnet County. The rocks take an excellent polish, have a very pleasing deep dark green color, and often have nicely contrasting areas of lighter color in them.

The amphibolites have a mineral alignment that produces a direction along which the rock splits easily. The alignment dips steeply in many deposits and would make quarrying more difficult than where it is flatter lying. With a more extended field examination, it should be possible to find deposits in which the mineral alignment dips less than 30°.

In some areas the amphibolites contain a large amount of biotite and approach biotite schist in character. Some of these rocks can be split into rather thin plates which has led to the assumption that they are slates. However, no true slates were seen in the pre-Cambrian of central Texas.

Description by Localities

Burnet County

LOCALITY BU–30

A deposit of amphibolite is located about 6 miles west of Burnet in an area of Packsaddle schist. It is near the hard-surfaced Llano-Burnet highway. The deposit at the surface is limited to boulders but may possibly be more massive with depth. It is hard and tough, takes a good polish, and is dark green with some white quartz veins and splotches. This stone could be used for terrazzo chips, but the quartz which it contains might be objectionable.

Llano County

LOCALITY LL–49

Location and geology.—A deposit of amphibolite is located about 9 miles west of Marble Falls and is well exposed in Pecan Creek, a short distance downstream from where the road crosses the creek. The road is graded but otherwise little improved. The amphibolite strikes N. 40° W. and dips 80° to the southwest. Elongated cigar-shaped objects in the amphibolite may possibly be stretched pebbles. They pitch 45° S. 35° E. and are aligned along the bedding of the amphibolite. Considerable pyrite is present in some layers of the amphibolite. When cut by a carborundum saw running in water, the amphibolite melts into blebs which are of sufficient size to rattle against the guards.

Megascopic description.—The amphibolite is predominantly deep dark green containing some areas which are mixtures of very light green and white. Pyrite is abundant as small particles elongated parallel to the structure of the dark-colored portion and as large grains and clusters of grains in the light-colored portion. The amphibolite takes a good polish.

Microscopic description.—The amphibolite is composed predominantly of hornblende and some quartz and andesine feldspar. Some light-colored areas in the rock are predominantly made up of diopside and a small amount of andesine feldspar. Some magnetite is present and pyrite is rather abundant. The hornblende is mostly oriented, and the average crystal is about 1/2 by 1/10 of a millimeter in size. The diopside grains are as much as 3 mm. in size.

Recommendations.—A large deposit of amphibolite is present. It contains a large amount of pyrite, which might be objectionable. The stone takes a good polish and has a pleasing color.

LOCALITY LL–51

A deposit of amphibolite is located north of the Llano-Round Mountain road and east of Sandy Creek. The distance from the deposit to Marble Falls is about 16 miles. The amphibolite is well bedded and splits readily into layers suitable for flagging. The rock is hard and should be very resistant to wear. The layers of rock from this deposit are in part slightly curved. The rock is dark colored and should be of value where a tough, hard, dark-colored flagging is needed.

LOCALITY LL–57

Location and geology.—A deposit of epidotized rock is located about 1 mile south of Sandy Creek, about 3 miles west of the Round Mountain—Llano road, and about one-half mile north of the V. V. Moss ranch house. The deposit is 20 miles from Marble Falls. The epidotized rock is exposed as a number of thin parallel bodies a few hundred yards long. It contains numerous quartz veins and is much jointed, and the size of block that can be obtained, therefore, is limited. The stone, even though of a beautiful green color, is probably of little value for building purposes. A small amount of surface stone was crushed for terrazzo chips. It was difficult both to crush and to cut because of its hardness and toughness.

Megascopic description.—The epidote rock is a mixture of small areas of epidote-green and dark green, producing a peppered green. Small tension cracks filled with quartz are numerous, and a few dark, ill-defined streaks or veins are present. The epidote takes a uniform but not brilliant polish, and the quartz veins take a mirror-like polish.

Microscopic description.—The epidote rock is composed predominantly of epidote. A small amount of feldspar, quartz, hornblende, and magnetite is present. The feldspar appears to be andesine in composition. Occasional millimeter-sized areas are composed entirely of quartz mosaics. Most of the rock is fine grained.

Recommendations.—This deposit is of no value for building stone.

Mason County

LOCALITY M–15

Location and geology.—Amphibolite outcrops on the north bank of Beaver Creek about 300 yards downstream from the Mason-Fredericksburg highway, 32 miles from Fredericksburg. Packsaddle schist is well exposed in a bluff about 30 feet high and consists of well bedded amphibolitic and feldspathic rocks and rarely mica schists. A small amount of injected quartz and feldspar parallels the bedding, and rarely a small area of epidote and garnet is present. Some closely compressed drag folding indicates that the outcrop as a whole is overturned and is a portion of a closely compressed fold. Only the slightest trace of cleavage can be found where the drag folding is best developed. The rock as a whole splits readily along the bedding and not in the direction in which cleavage is indicated. Even though much of the rock can be split rather thinly it is not a slate and cannot be used for slate. The thickness of splitting is controlled by the bedding, which is not uniform; consequently, a uniform product cannot be obtained. This rock, however, would be excellent for flagging. The bedding dips 60° N. 35° E. The axial lines of the drag folds pitch 52° to the east, and the axial plane strikes N. 45° W. and dips 57° to the northeast.

Megascopic description.—The amphibolite is dark greenish black and fine grained. The small hornblende crystals reflect glittering points of light. The stone splits with a smooth surface. None of this stone was polished, but if it is similar to other amphibolites it should take a good polish. Some beds are feldspathic and are consequently lighter colored.

Recommendations.—This deposit of amphibolite is chiefly of value for flagging.

GNEISS

Description by Localities

Burnet County

A large area of Valley Spring gneiss is located in western Burnet County west of Burnet and is traversed for several miles by a hard-surfaced highway. This area appears to contain two somewhat different gneisses. The more banded portion of the Valley Spring gneiss is separated from the Packsaddle schist in the vicinity of the Miller and Clemson graphite property (formerly Southwestern Consolidated Graphite Company) by a less banded, less micaceous, and more massive pink gneiss. The massive gneiss is of value for building stone. It is well exposed south and east of the graphite mine as large rounded domes which are rougher in contour than most granite domes. The part of the gneiss area containing stone suitable for building is shown in figure 2. This figure was prepared for a circular on graphite[58] and consequently does not outline the entire area of the gneiss. Niggerhead, which is farther west, is probably composed of a similar type of gneiss, and undoubtedly other areas suitable for building stone are present elsewhere in this portion of Burnet County.

The Llano-Burnet highway is just south of the area shown in figure 2. The nearest point to Burnet along this highway where gneiss outlined as of building stone quality

[58]Barnes, V. E., Additional notes on graphite in Texas: Univ. Texas, Bur. Econ. Geol., Min. Res. Circ. 15, 11 pp., July, 1940.

occurs is about 8 miles. The distance from Burnet to the most favorable place for quarry sites in the vicinity of the graphite mine is about 9 miles.

Little attention was paid to the gneiss during the field examination of building stones; consequently, samples of these stones were not collected and physical tests are not available. However, from the stone's toughness and from its appearance and topographic expression, it must be extremely strong and durable.

A polished surface is not available for a megascopic description, but in the field many surfaces are sufficiently smooth so that the texture and color of the stone are easily ascertained. The gneiss is medium grained and of a pink color from the predominant mineral, microcline. A small and variable amount of dark minerals is present, giving the stone the non-uniform banded appearance so highly desirable in gneisses used for building stone.

The highly banded gneiss has rather closely spaced bedding joints and is darker in color due to a greater amount of biotite. It might be usable for building stone. H. B. Stenzel has obtained analyses for the darker colored gneiss from two localities in Burnet County. The analyses, made at the Minnesota Rock Analyses Laboratory, Minneapolis, are given in Table 46.

Table 46. Chemical analyses of Burnet County gneisses.

	30793	30928
	Per cent	
SiO_2	71.10	70.92
Al_2O_3	12.16	15.72
Fe_2O_3	2.02	0.63
FeO	1.59	0.79
MgO	0.94	0.48
CaO	1.08	0.95
Na_2O	1.00	5.55
K_2O	8.75	4.31
H_2O+	0.13	0.11
H_2O-	0.08	0.04
CO_2	0.41	0.03
TiO_2	0.33	0.33
P_2O_5	n.d.	0.07
MnO	n.d.	0.01
F	n.d.	0.13
	99.59	100.07
Less O=F		0.05
		100.02

30793. Valley Spring gneiss, Burnet County; 5 feet beneath surface in cut north side of Llano-Burnet highway, 7.2 miles west of highway intersection in Burnet; collected by V. E. Barnes and C. A. Parkinson; R. W. Perlich, analyst.

30928. Valley Spring gneiss, Burnet County; from north ditch of old Llano-Burnet road, on east slope of a small hill, 1.56 miles west from point where this road forks from new Llano-Burnet highway; collected by H. B. Stenzel; R. B. Ellestad, analyst.

The normative mineral composition as calculated from the analyses and the mode of No. 30793 for comparison are given in Table 47.

Table 47. Normative and modal mineral compositions of Burnet County gneisses.

	Norm 30793	Norm 30928	Mode 30793
	Per cent		
Quartz	28.86	20.22	27
Orthoclase	51.71	25.58	67
Albite	8.38	46.63	
Anorthite	3.06	2.78	
Corundum	....	0.92	
Hypersthene	2.96	1.60	
Magnetite	3.02	0.93	2
Ilmenite	0.61	0.61	
Apatite	....	0.17	
Calcite	0.93	0.07	
Fluorite	....	0.27	
Biotite	....	....	4
Normative plagioclase	$Ab_{73}An_{27}$	$Ab_{94}An_{6}$	
Symbol	I″.″4.1″.(1)2.	I.4.1″.″4.	

Specimen No. 30793 is composed predominantly of microcline and quartz and some plagioclase and biotite. Magnetite, titanite, and apatite are the main accessory minerals. The estimated mineral composition of the gneiss is quartz 27, feldspar, mostly microcline, 67, biotite 4, and magnetite 2 per cent. Included in the 4 per cent of biotite is considerable chlorite and green mica. The feldspars are all uniformly and rather deeply clouded, indicating considerable alteration by weathering. The norm indicates the presence of nearly 1 per cent calcite, but calcite as a mineral of microscopic size was not seen. The norm also indicates about 11 per cent of plagioclase having a composition of $Ab_{73}An_{27}$. This plagioclase is rather well masked by weathering and is very difficult to distinguish from the microcline. One crystal was found in which the composition could be determined, and its composition is about $Ab_{80}An_{20}$.

Specimen No. 30928 has not been thin sectioned. A powdered sample reveals quartz, microcline, and albite to be about equally abundant. Biotite is the chief femic mineral. Accessory minerals recognized are apatite and magnetite. The albite from its index of refraction and other optical properties has a composition of about $Ab_{92}An_8$. The feldspars and biotite are exceedingly fresh.

Gillespie and Llano Counties

LOCALITY LL–38

Location and geology.—A deposit of gneiss is located in the town of Llano about 150 yards north of the railroad near the Norton granite works. The gneiss has been used extensively for local building. It is a fine-grained gneissic rock, is well bedded, and is well suited for the purpose for which it has been used.

Megascopic description.—The gneiss is well banded with small black specks throughout all bands. The bands range in color from pasty white to a dark bright gray. The lighter colored bands are mostly tinted with pink. The mass color of the gneiss as viewed at a distance is a slightly pinkish medium gray. It takes an excellent polish.

Microscopic description.—The gneiss is composed of microcline, plagioclase, hornblende, biotite, magnetite, apatite, calcite, chlorite, and rutile. Microcline is by far the most abundant mineral, and oligoclase is rather plentiful. Hornblende and biotite make up only a small portion of the rock. Quartz was not found in thin section, but a powdered sample was found to contain a very small amount of quartz. Calcite is only sparingly present. The chlorite is mostly an alteration product of biotite. The biotite is not strongly pleochroic, thus suggesting a low iron member of the series. The average grain size of the gneiss is about one-fourth of a millimeter, and the maximum grain size is about 1 mm. The hornblende and biotite have a roughly preferred orientation parallel to the banding of the rock. Orientation of other minerals is not noticeable.

Recommendations.—The gneiss is of value for local building but is not of value for cut stone.

Miscellaneous Localities

H. B. Stenzel obtained analyses of four gneiss samples, three from Llano County and one from Gillespie County. These analyses were made at the Minnesota Rock Analyses Laboratory, Minneapolis, and are given in Table 48.

Table 48. Chemical analyses of gneisses from Gillespie and Llano counties.

	30791	30792	30929	30930
	Per cent			
SiO_2	72.62	74.11	76.47	74.91
Al_2O_3	12.93	13.58	11.64	11.78
Fe_2O_3	1.49	1.14	0.50	2.08
FeO	1.54	0.77	1.26	0.54
MgO	0.36	0.12	0.38	0.06
CaO	1.15	0.99	0.10	0.03
Na_2O	3.77	3.40	1.41	0.36
K_2O	4.71	5.13	7.79	10.06
H_2O+	0.28	0.05	0.18	0.00
H_2O-	0.05	0.03	0.02	0.02
CO_2	0.44	n.d.	0.02	0.01
TiO_2	0.21	0.24	0.11	0.14
P_2O_5	n.d.	n.d.	0.02	0.02
MnO	n.d.	n.d.	0.02	0.01
	99.55	99.56	99.92	100.02

30791. Valley Spring gneiss, Llano County; 6 feet below top of west wall of Premier gray granite quarry 2.7 miles south of Sixmile; sampled from light-colored portion of steeply dipping gneiss-schist series. Collected by V. E. Barnes and G. A. Parkinson; R. W. Perlich, analyst.

30792. Valley Spring gneiss, Gillespie County; east side of highway cut north of Bell Mountain, 2 miles by road southwest of Legion Creek bridge, and about 500 feet south of a concrete culvert. Collected by V. E. Barnes and G. A. Parkinson; R. W. Perlich, analyst.

30929. Valley Spring gneiss, Llano County; east side of highway cut near Baby Head and near llanite dike. Collected by H. B. Stenzel; R. B. Ellestad, analyst.

30930. Valley Spring gneiss, Llano County; 1.8 miles east of road intersection at Baby Head, on creek parallel to Wilberns Glen road, from a ledge which forms a water fall. Collected by H. B. Stenzel; R. B. Ellestad, analyst.

The normative mineral compositions as calculated from the analyses are given in Table 49.

Table 49. Normative mineral composition of gneisses from Gillespie and Llano counties.

	30791	30792	30929	30930
	Per cent			
Quartz	30.36	32.46	36.66	34.14
Orthoclase	27.80	30.02	46.15	59.49
Albite	31.96	28.82	12.05	3.14
Anorthite	2.78	5.00	0.56	0.14
Corundum	0.51	0.61	0.61	0.31
Hypersthene	2.09	0.43	2.75	0.10
Magnetite	2.09	1.62	0.70	1.16
Hematite	none	none	none	1.28
Ilmenite	0.46	0.46	0.15	0.30
Apatite	———	———	0.05	0.05
Calcite	1.00	———	0.05	0.02

	Normative plagioclase	Symbol
(30791)	$Ab_{92}An_8$	I."4.1".3.
(30792)	$Ab_{85}An_{15}$	I."4.(1)2.3.
(30929)	$Ab_{96}An_4$	I.3(4).1.2.
(30930)	$Ab_{96}An_4$	I.(3)4.1.1.

The mineral composition of these gneisses is very similar to that of the granite of the area, except that Nos. 30929 and 30930 are higher in microcline (orthoclase) and lower in plagioclase (albite and anorthite). However, these gneisses are probably of sedimentary origin. The calcite content of No. 30791 is excessive. The rest, so far as revealed by the analyses, are made up of stable minerals which will not readily deteriorate because of weathering.

Mason County

LOCALITY M-24

Location and geology.—A deposit of gneiss is located about 9.5 miles northeast of Mason. It is along the Pontotoc road 1 mile east of the Mason-Fredonia road and is exposed in Willow Creek at the road crossing. The size of the gneiss mass was not ascertained. The gneiss was found too late for physical tests to be made on it, and it is included here as a matter of record because of its unusual appearance, even though the areal extent and physical properties are unknown.

Megascopic description.—The gneiss has a very striking appearance, attractive to many and repellant to others. To those who do not like it, the chief objection apparently is the combination of color and distribution of minerals, which reminds them of serpents. The gneiss is composed of microcline areas one-quarter to one-half of an inch in size of a much deeper red color than is usual for microline, distributed in a groundmass of dark gray. The microcline is triaxial ellipsoidal in shape and has a parallel orientation; consequently, the shape of the microcline areas varies widely but uniformly, depending on the direction in which the stone is cut. A cut parallel to a plane which includes the directions of maximum elongation and greatest shortening has the most pronounced parallelism and consequently the greatest difference in the dimension of the microcline areas. In a direction at right angles and still crossing the banding the feldspars are chubby but yet well aligned. In both these directions the darker constituents weave in and out between the microcline areas producing a decidedly wavy (serpent-like) structure. A cut parallel to the banding of the gneiss produces a surface with larger microcline areas in a more coarsely netted groundmass than is found in either of the other sections. The gneiss would be ideal for decorative purposes in which the same color is needed but in which different textures are desirable.

Microscopic description.—The gneiss is composed predominantly of microcline, quartz, plagioclase feldspar, and biotite. The biotite is very dark colored and in part has altered to a very dark green chlorite in which a reticulated mineral is present. The biotite is too dark in color to allow the detection of any included mineral. The gneiss contains a small amount of hornblende. Some titanite is recognizable and for the most part is deeply clouded by leucoxene. Magnetite, apatite, and zircon are the chief accessory minerals. The plagioclase is of an oligoclase composition. The oligoclase is fresh, and the microcline is slightly clouded by alteration. The gneiss contains some pyrite as scattered grains and small clusters of grains.

Recommendations.—The distribution and amount of gneiss present are unknown. The color is unusual and to some persons is very attractive. The pyrite which is contained might be objectionable, but at the outcrop no decomposition of pyrite was noticed. The extent of the gneiss should be determined.

Paleozoic Building Stone

A brief review of the central Texas Paleozoic stratigraphic column with mention of favorable building stone beds is given on pages 12–15.

Sandstone

PROPERTIES

Definition.—Holmes[59] gives the following definition of sandstone: "A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

[59]Holmes, Arthur, The Nomenclature of Petrology, Thomas Murby and Co., London, p. 203, 1920.

Mineralogical varieties such as feldspathic and glauconitic sandstones are recognized, and also argillaceous, siliceous, calcareous, ferruginous and other varieties according to the nature of the binding or cementing material."

Mineral and chemical composition.—Sandstones are predominantly composed of quartz and in addition contain many other minerals in various amounts. The more common of the detrital minerals are microcline, plagioclase, muscovite, and biotite. A large number of other minerals of the heavy mineral group such as magnetite, garnet, hornblende, tourmaline, zircon, and rutile may be present. In addition to the detrital minerals, sandstones may contain grains of glauconite, pyrite, and organic material. The cements of sandstone commonly are minerals such as limonite and other iron oxide minerals, calcite, dolomite, quartz, chalcedony, opal, and the clay minerals.

The chemical composition of sandstone will vary widely depending upon the mineral assemblage present. A pure quartz sandstone cemented by silica might closely approach 100 per cent silica in composition. An analysis of a sandstone composed of numerous minerals is given in Table 50 to show the chemical complexity of some sandstones. An approximate mineral composition, based on minerals present, calculated from the analysis is also included in the table.

Table 50. Lion Mountain sandstone, Mason County. Sample from bluff on west bank of Squaw Creek 1500 feet north and 500 feet east of milepost 29 of Gillespie-Mason County line. Analysed by R. B. Ellestad, Minnesota Rock Analyses Laboratory, Minneapolis.

Chemical analysis	*Per cent*	Mineral composition	*Per cent*
SiO_2	69.24	Quartz	49.02
Al_2O_3	2.23	Albite	1.05
Fe_2O_3	17.14	Ilmenite	0.30
FeO	1.20	Apatite	1.68
MgO	1.58	Calcite	0.90
CaO	1.71	Dolomite	0.74
Na_2O	0.08	Hematite	7.36
K_2O	2.99	Pyrite	0.09
H_2O+	1.82	Glauconite	38.86
H_2O-	0.52		
CO_2	0.77		
TiO_2	0.14		
P_2O_5	0.69		
MnO	0.03		
BaO	0.00		
S	0.03		
	100.17		

The chemical composition of a sandstone is of little importance in determining its value as a building stone except as an aid in determining the presence of minerals which might be objectionable.

Texture and color.—Sandstones may be composed of grains which are rounded almost to spheres or of grains which may be angular without rounding. An arbitrary limit for the grain size of sandstones has been set between about 1/16 to 2 mm. in diameter. The grains may be well sorted in some deposits and may be little sorted and of all sizes in others. Some sandstones may contain considerable silt and clay, and others may contain some grains in excess of 2 mm. in diameter. The space between grains may be filled or may be practically empty. The distribution and size of the grains and of the space between grains constitute the texture of a sandstone.

The color of a sandstone chiefly depends on the color of the cementing agent and of the grains. A quartz sandstone with a colorless cement is white. A glauconitic sandstone is green. Sandstones which are red, brown, yellow, and buff mostly have a cement which is composed in part at least of hematite and limonite. These colors are stable, whereas blue and gray colors may be unstable.

Specific gravity, porosity, and strength.—Sandstones are relatively light-weight building stones. The Wisconsin[60] sandstones have a porosity ranging from 4.81 to 28.28 per cent. The dry weight of these stones ranged from 115.55 to 149.92 pounds per cubic foot, and the crushing strength ranged from 1658 to 13,669 pounds per square inch. The Wisconsin sandstones are probably representative, and the above values give some indication of these properties in sandstones.

CENTRAL TEXAS PALEOZOIC SANDSTONES

Resumé.—Of the many sandstone deposits available in central Texas, only a few are described in this publication. Some of those described are distinctly not of economic importance except locally and are mentioned only because they have been

[60]Buckley, E. R., Building and ornamental stones of Wisconsin: Wisconsin Geol. Nat. Hist. Survey, Bull. 4, pp. 393-395, 402-403, 1938.

used. Other outcrops containing much more easily worked stone have not been utilized because of their distance from local communities. Sandstone in this area is in direct competition with the much easier worked cream-colored limestones of the Cretaceous, and unless there is a swing to somber-hued stone in building, the buff and brown sandstones of this area will not be much used.

The most extensive sandstone of central Texas is the Hickory sandstone of Cambrian age. It varies widely in color, grain size, texture, and mineral composition. Two samples were examined microscopically. These are composed predominantly of quartz and contained abundant microcline and plagioclase. Other minerals present are glauconite, calcite, muscovite, limonite, magnetite, biotite, and hornblende. Some portions of the Hickory sandstone are dark red from a hematite cement. This sandstone is friable and not suited to building. Some is almost white, cross-bedded, and friable. The more compact and weather-resisting varieties are rather fine grained, buff to brown, and are in beds of uniform thickness. The sandstone of building grade is mostly within the transitional zone from Hickory sandstone to Cap Mountain limestone and is located, as now defined, mostly in the bottom sandy portion of the Cap Mountain limestone member of the Riley formation. The bottom portion immediately above a dreikanter conglomerate[61] is mostly highly cross-bedded, is probably eolian in origin, and is of little value for building.

The Welge sandstone member of the Wilberns formation is a uniform-grained, brown sandstone more or less cross-bedded. The sandstone is resistant to weathering and throughout much of its outcrop area forms a scarp. Many of the quartz grains of the sandstone have been somewhat enlarged by addition of silica with the development of crystal faces which reflect light, causing the sandstone to glitter. Samples were not collected from the Welge sandstone for physical testing, and consequently little is known of its value as a building stone. It is about 24 feet thick in Gillespie County and outcrops throughout Mason, McCulloch, San Saba, Llano, Blanco, and Burnet counties, except where overlapped by younger formations or cut out by faulting. In Burnet County the Welge sandstone is somewhat glauconitic.

The Smithwick shale contains some sandstone beds in Burnet County. The sandstone is hard and resists weathering. The beds range up to about 6 inches in thickness and are separated by shale zones. The sandstone is of value only for local building.

The Strawn group of beds of the Colorado Valley consists largely of alternating beds of sandstone and shale. Only six localities were examined during the building stone investigation. There are many other localities containing sandstone suitable for building. The mineral assemblages of these sandstones are somewhat varied with quartz predominant and feldspar plentiful. The sandstones are predominantly fine grained and mostly range from light buff to brown in color. Sandstones, color banded in reds, yellows, and grays, are locally abundant.

The location of the following described sandstones is shown in Plate 1.

Cambrian Sandstone

Description by Localities

Blanco County

LOCALITY BL–13

Location and geology.—A sandstone deposit is located 9.25 miles from Johnson City along the road to Sandy post office. The nearest railroad is at Marble Falls, a distance of 20 miles by road, 13 miles of which is hard surfaced and the rest of which is graded but not otherwise improved. The sandstone is somewhat glauconitic and is exposed in an area 200 by 200 feet in size as a smooth surface without joints. It dips gently to the southeast. The sandstone is reddish and apparently extends over a wide area under very little cover. The sandstone is within the transitional zone between the Hickory sandstone and the Cap Mountain limestone and falls within the area mapped as the Hickory sandstone member of the Riley formation.

[61]Barnes, V. E., and Parkinson, G. A., Dreikanters from the basal Hickory sandstone of central Texas: Univ. Texas Pub. 3945, pp. 665–670, 1939 [1940].

The sandstone has a red color and is mottled with areas of dark red in a groundmass of dull lighter red. The sandstone contains sufficient glauconite to give it a faint greenish cast. It is a fine rather uniform-grained sandstone.

Microscopic description.—The sandstone is composed predominantly of quartz and contains considerable microcline, plagioclase, and glauconite, and a small amount of calcite, muscovite, and limonite. The latter is present as a cloudy material having a reddish appearance and may, in part, have been derived by weathering of glauconite. The sand grains are predominantly angular.

Recommendations.—Considerable rather massive sandstone is available at this locality which could be used for local building. Its color is rather somber, and it is far from a railroad.

Burnet County

LOCALITY BU–43

Location and geology.—A sandstone deposit is located 1.5 miles north of the railroad at a point 2 miles west of the Fairland railroad junction north of Marble Falls. The sandstone has been extensively quarried. At one time a railroad spur extended to the quarry which has not been active in many years even though much good stone is present. The quarry is located within the transitional zone from sandstone to limestone and, as now mapped, falls within the basal part of the Cap Mountain limestone member of the Riley formation. The sandstone contains a small amount of glauconite, and shaly layers separate some of the sandstone beds. The beds range mostly from 1 to 2 feet in thickness.

The sandstone is calcareous cross-bedded and is light grayish brown, having a superficial resemblance to some types of wood. Some of the cross-bedding is well preserved, and some is sufficiently disturbed by filled burrows so that only a general alignment is present. The sandstone is fine grained and contains a rather uniform but small amount of glauconite.

Microscopic description.—The sandstone is predominantly quartz and contains abundant microcline and calcite. Other minerals present are plagioclase, glauconite, biotite, muscovite, magnetite, limonite, and hornblende. The biotite is mostly of a green color, indicating some alteration. The sandstone is rather fine grained and the grains are predominantly angular.

Recommendations.—The sandstone is of a pleasing light color, is a durable sandstone, is of good quality, and a large amount is present. It is a desirable building stone.

Llano County

LOCALITY LL–3

A deposit of sandstone is located near the southwestern edge of Dancer Flats in the Riley Mountains about 9½ miles by road southeast of Llano. The sample is within the transitional zone from sandstone to limestone and, as now mapped, falls in the basal portion of the Cap Mountain limestone member of the Riley formation. The sandstone is predominantly red, contains glauconite, and is in beds up to 1 foot thick. The sandstone is of a uniform dull reddish-brown color and contains rather abundant small fragments of linguloid brachiopods. It is a medium-grained rather thin-bedded sandstone and is of value only for local building.

Mason County

LOCALITY M–1

A sandstone deposit of Cambrian age is located about 1.5 miles southwest of Mason and a short distance west of the Honey Creek road. It has been used extensively in Mason for business buildings and residences, including the Mason County courthouse. A quarry has been opened which is 20 feet wide and three-quarters of a mile long. Mr. Parkinson reports that in 1932 a 1- to 3-foot bed of sandstone was exposed at the bottom of the quarry. In 1939 slumped sand and soil had covered the building stone bed. The sandstone above the quarry bed appears to be of no value as a building stone. The sandstone is light grayish brown and is flecked by abundant small dark brown millimeter-sized spots. It is a fine-grained sandstone. The sandstone used from this deposit is lasting very well in the buildings of Mason. The bed in general is too thin to quarry except for local use.

San Saba County

LOCALITY S–26

A sandstone deposit is located about three-fourths of a mile south of Cherokee and one-fourth of a mile east of the highway. It is exposed in the bed of Jackson Branch which at this point is a slightly incised stream in a rather featureless flat area. A small amount of stone was reported to have been quarried from this deposit for use in the Cherokee College building. The most usable bed is about 12 inches thick and is rather distinctly bedded. The rest of the sandstone is thinner bedded and is mostly in beds 6 inches or less thick. The sandstone beds alternate with somewhat glauconitic shaly layers, and the deposit is in the zone of transition from sandstone to limestone and, as now mapped, falls in the basal portion of the limestone member of the Riley formation. The stone is light brown and at the outcrop is very friable. It may harden upon exposure to the air. The outcrop is mentioned because stone has been used from it and not because it is of commercial importance.

Pennsylvanian Smithwick Sandstone

Description by Localities

Burnet County

LOCALITY BU–2

A deposit of sandstone is located along Sycamore Creek about 6.5 miles by road east-northeast of Marble Falls. The road is graded for about half the distance and is in poor condition for the rest of the way. The sandstone is in the Smithwick formation and consists of four hard beds which might be utilized as a local building stone. Hard sandy layers are rather common in this portion of the Smithwick formation. The sandstone is even textured and fine grained. It is mostly gray to yellowish-gray.

Microscopically the sandstone is seen to be composed predominantly of quartz grains somewhat secondarily enlarged. A small amount of feldspar, magnetite, and chlorite is also present. Interstitial calcite appears to be the chief cementing material. The sandstone is strong and has other desirable physical qualities. It is present in thin beds and is of value only for local building.

LOCALITY BU–3

A sandstone outcrop is located along the Smithwick road about 4.5 miles east of Marble Falls. It is exposed in rather thin beds in the road and in pastures on each side of the road. The sandstone varies in color from gray to faint yellowish gray to dull reddish gray. It is an even-textured fine-grained sandstone which is of value only for local building.

Pennsylvanian Strawn Sandstone

Description by Localities

Lampasas County

LOCALITY LM–2

A sandstone deposit is located along the Lometa-San Saba highway about 200 yards east of the Red Bluff bridge and about 1 mile south of the railroad. It outcrops in highway cuts and in pastures along both sides of the road. The sandstone is rather soft, is yellowish tan, and is in a massive bed about 2 or 3 feet thick. Outcrops are scarce and the presence of other beds in the area was not determined. The sandstone is mostly of value for local building.

LOCALITY LM–3

A sandstone deposit located about 3 miles west of Nix in western Lampasas County is about one-half mile north of the main road leading west from Nix. The deposit is about 12 miles by road from the nearest railroad, which is at Lometa.

F. B. Plummer mapped this area during 1940, noting the location of places from which the sandstone has been produced. At the eastern end of the outcrop area, four beds varying between 8 and 18 inches in thickness are distributed through about 18 feet of the Strawn formation. The sandstone is of uniformly fine grain. It is well bedded and splits easily along the bedding into smooth-surfaced flags, yet the bedding can scarcely be seen. Much of the stone is color banded with the color bands transverse to the bedding. In many joint blocks the color bands are circular to elliptical annular-like bands which simulate somewhat the bands in petrified wood. The band colors are combinations of pink and yellow, pink and gray, and yellow and gray. Some of the stone is pastel pink without color banding. The sandstone is being produced for flagging, only that which is color banded being used. The solid-colored stone is being discarded. Much waste is produced by the present crude methods of quarrying.

The sandstone appears to be somewhat too friable to be used for flagging but should be suitable for walls and interior trim. The several members of the sandstone vary somewhat in hardness. With selection some stone might be obtained suitable for flagging.

The sandstone was traced for about one-half mile westward and, according to Plummer, continues in this direction for a considerable distance. There is a large amount of sandstone available, and undoubtedly other members in the Strawn will be found which are usable. Physical tests were not made on this sandstone. Before it is considered for exterior use, physical tests should be made on it.

Mills County

LOCALITY MILLS–1

A sandstone quarry is located about 200 yards north of the old Shadrick Mill on the eastern banks of Colorado River, in the southern tip of Mills County. The quarry is about 1 mile north of a railroad and is on a point formed by the junction of Antelope Creek and Colorado River. The rock quarried at this locality was obtained from beds 18 inches thick about 50 feet above river level. Four other beds, each about 18 inches thick, outcrop at a slightly lower elevation. The second ledge from the top contains a layer of hard limonite-impregnated sandstone and is valueless. A 5-foot bed of very uniform-textured sandstone which is free of plant markings is located near creek level. Most of the upper beds contain numerous fragmentary plant impressions. At the time this sandstone was examined a 60-foot flood had recently inundated it, covering it with a layer of mud.

The sandstone is of a uniform light gray color with a very slight brownish tint. It is medium grained and has a few small reddish-brown fossil plant markings in it. The sawed stone has a uniform surface with a very harsh feel, indicating that it might be of value for grinding stones. The sandstone appears to be of fair quality.

San Saba County

LOCALITY S–2

Location and geology.—A sandstone deposit is located about 2 miles west of the hard-surfaced San Saba-Goldthwaite highway at a point 5.7 miles north of San Saba and about 0.7 mile north of the east-west road. A shallow quarry at least 400 feet long has been opened along the brow of a ridge. The sandstone is fine grained and mostly too thin bedded to be used. One massive bed at the bottom of the quarry varies from 4 to 6 feet in thickness and is the best ledge of stone exposed. Two widely spaced sets of joints trending east-west and N. 10° E. are an aid in quarrying the stone. The upper thin-bedded sandstone contains numerous plant fossils.

The sandstone was used in the attractive San Saba grade school building, built in 1910. Thirty years of exposure has not affected the sandstone even where the base course is in contact with the soil and where roof drains have been pouring water down the sides of the building. It remains practically the same color as when quarried. The sandstone is medium grained, is uniform in texture, is of a uniform buff color, and appears to be a very good sandstone.

Microscopic description.—The sandstone is composed predominantly of quartz and contains microcline, plagioclase, muscovite, and altered biotite. Some heavy minerals such as magnetite, tourmaline, and garnet are present. Some of the quartz is reticulate. The cement is cloudy and ranges from white to yellow in color. The grains range in shape from subangular to fairly well rounded.

Recommendations.—The sandstone is of good quality and withstands weathering. The usable sandstone seen is limited to one bed, indicating that the quantity present is not large.

LOCALITY S-15

Location and geology.—A sandstone deposit is located about 1 mile east of Hall and about 500 feet north of the railroad. The sandstone forms a south-facing scarp about 15 feet high. It is in beds ranging up to 18 inches in thickness, with most beds averaging about 6 inches in thickness. It is fine grained, of a buff color, rather hard, and apparently is resistant to weathering. The sandstone has been used for local building and is good for this purpose. The sandstone is of a light buff color and is faintly mottled. It is fine grained and has occasional millimeter-sized black areas distributed through it.

Microscopic description.—The sandstone is composed of small angular quartz grains, widely spaced in a very fine-grained cloudy matrix which is brown by transmitted light and white with yellow areas by reflected light. In addition to quartz there is some microcline, muscovite, and chlorite. The rock is more nearly a siltstone than a sandstone.

Recommendations.—The sandstone is thin-bedded but otherwise appears to be of good quality. This sandstone is of value for local building.

LOCALITY S-21

Location and geology.—A deposit of sandstone is located a few hundred yards west of the San Saba-Chappel road at a point 11.3 miles southeast of San Saba. The road to San Saba is graded but otherwise little improved. The sandstone caps a long low ridge and is present in beds up to 8 inches in thickness. It splits well along the bedding and is very light colored. The sandstone has been used to some extent for local building and is very good for this purpose. The sandstone is mostly of a light buff color and contains a few millimeter-sized black specks. It is medium grained and is harsh to the touch.

Marble

The properties of marbles are reviewed on pages 91–93. The marbles included in this section are calcite and dolomite marbles which have not been metamorphosed but which are sufficiently compact to take a polish. "Marble" is used throughout the following sections in its commercial sense, not its geological sense. The various formations and members of the Paleozoic are defined as limestones and dolomites in the literature, and since this is a publication primarily for the use of persons interested in building stones, strict stratigraphic nomenclature is not always followed.

CENTRAL TEXAS PALEOZOIC MARBLES

Resumé.—The central Texas Paleozoic marbles are divided into groups having dominant characteristics. These groups mostly correspond to individual formations except for the formations of the Ellenburger group. The field investigation of building stones was made before the units of the Ellenburger were established, and little attempt has been made to distinguish between the dolomites of the Cambrian and Ordovician. The Cambrian dolomite is, therefore, included with the dolomites of the Ellenburger group even though it is a portion of the Wilberns formation.

The marbles are discussed under the following headings:

- Cap Mountain marbles—limestone in the Cap Mountain limestone member of the Riley formation
- Wilberns marbles—Morgan Creek limestone member, San Saba limestone member, and limestone beds in the Point Peak shale member of the Wilberns formation
- Ellenburger marbles including Cambrian dolomite:
  - Calcite marbles—limestones of the Tanyard, Gorman, and Honeycut formations
  - Dolomite marbles—dolomites of the Tanyard, Gorman, and Honeycut formations of the Ellenburger group and the Pedernales dolomite member of the Wilberns formation
- Mississippian marbles—Chappel limestone and limestone in Barnett formation
- Pennsylvanian marbles—Marble Falls limestone

The Cap Mountain marbles are composed predominantly of calcite and are mostly brown; a few are gray. Glauconite is always present and detrital minerals such as quartz, feldspar, biotite, and muscovite are present in most samples. These marbles take a fair but not brilliant polish. Only four Cap Mountain marbles were sampled, one in Blanco County and three in Burnet County. The Cap Mountain limestone member of the Riley formation extends, however, throughout Llano, San Saba, Mason, McCulloch, and Gillespie counties, except where overlapped by younger formations or cut out by faults. Some outcrops of the Cap Mountain limestone member in Gillespie County are shown in figures 3, 11, and 13.

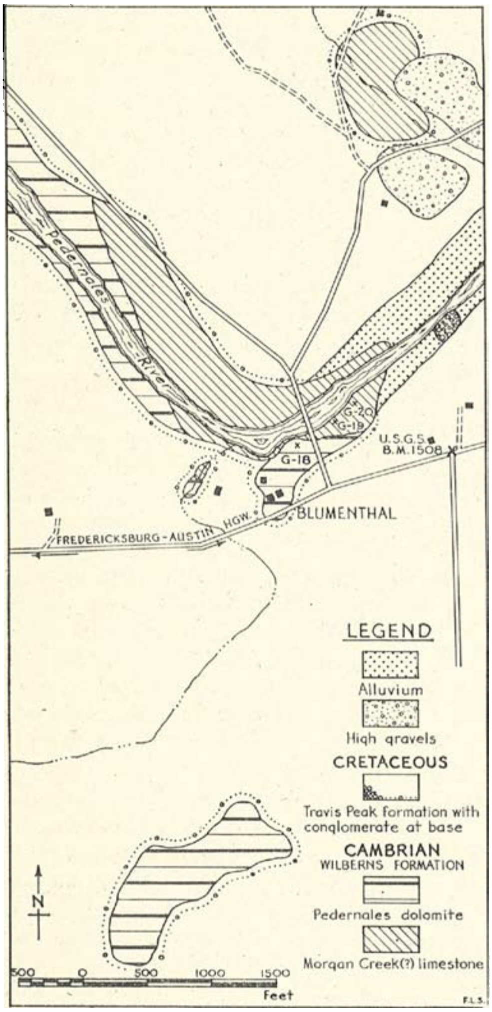

Fig. 14. Geologic map of an area around Blumenthal, Gillespie County, Texas.

The Wilberns marbles are of four distinct types. The largest marble deposits in this formation are massive bioherms which may attain a thickness of 100 feet and be several square miles in extent. These bioherms have been variously referred to as reefs, algal reefs, cryptozoans, and stromatoperoids. All these forms and others are included under the general term stromatolites. The stromatolite marbles are predominantly light bluish-green and are somewhat mottled. They occur at various levels within the Wilberns formation but are most common in the central portion. A quarry was opened in a faulted bioherm in Mason County and was abandoned (fig. 15). Large areas of unfaulted stro-

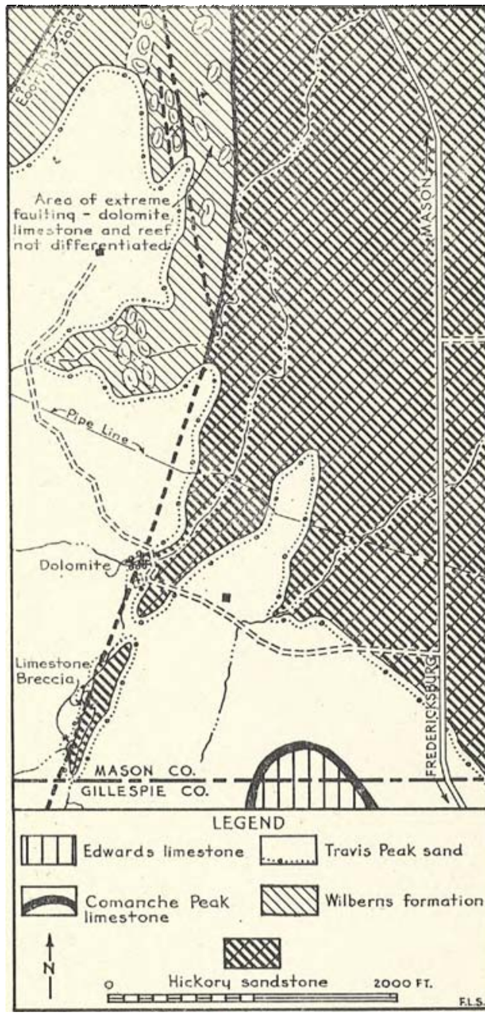

Fig. 15. Geologic map of an area in Mason County, Texas, 1.5 miles north of Cherry Spring, Gillespie County.

matolite marbles are present in Gillespie County (fig. 13) and suitable quarry sites are numerous.

In Llano County a series of beds (portion of San Saba limestone member of the Wilberns formation) containing spherical *Girvanella* one-fourth to one-half inch in

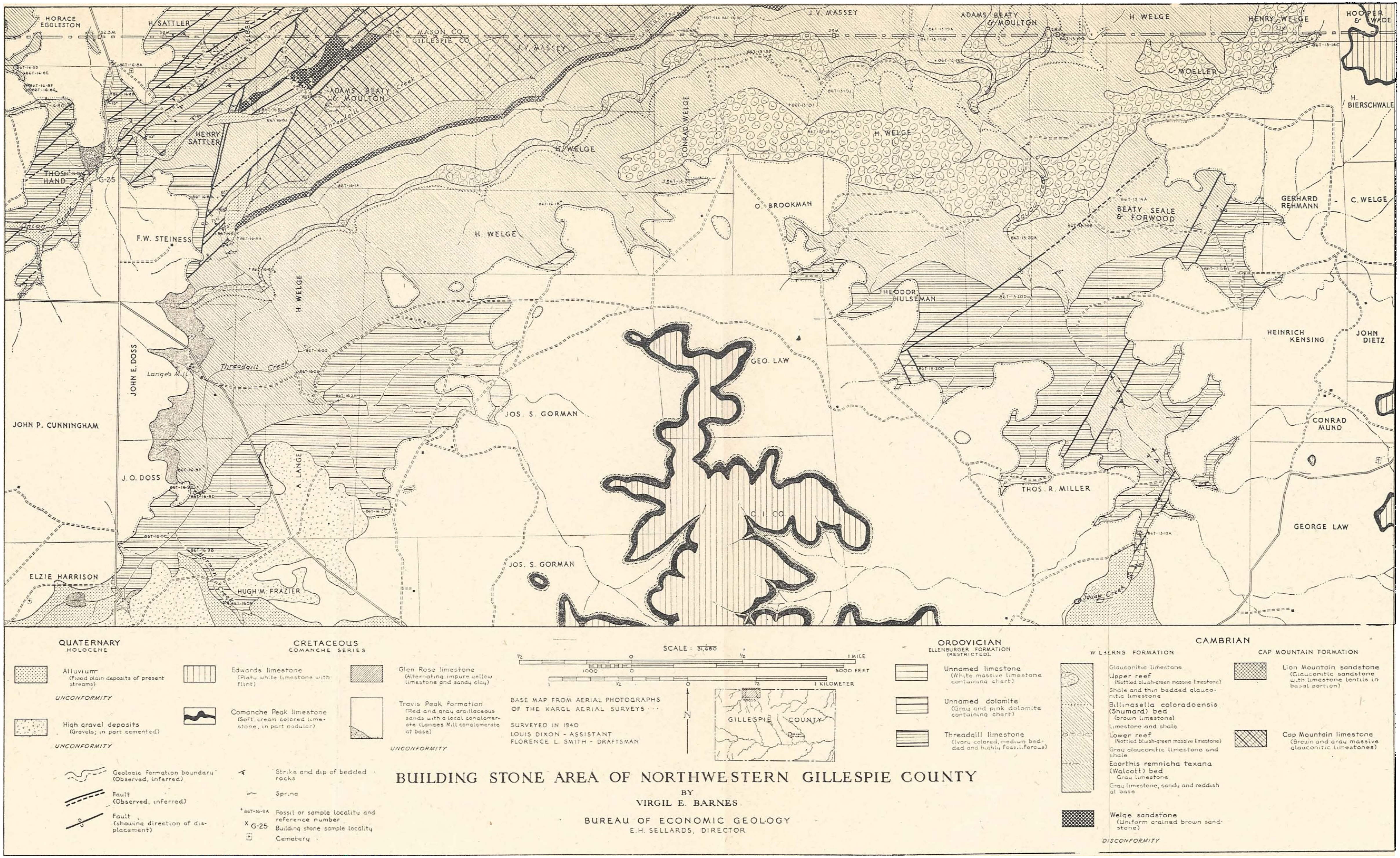

Fig. 13. Geologic map of Lange's Mill area, northwestern Gillespie County, Texas.

size are well exposed north of Lone Grove. These beds are well developed elsewhere in the western and northern part of the Wilberns outcrop area. The *Girvanella* marble has a striking appearance with the light-colored *Girvanella* contrasting well with the cream to light yellow matrix. Upon heating, the matrix becomes a pleasing shade of red and the *Girvanella* remain white. Much of the *Girvanella* marble is thin bedded and suited only for pitched face stone. Other portions of the marble are massive, and beds 5 feet or more thick can be quarried.

Edgewise conglomerate is abundant as thin beds mostly in the Point Peak member of the Wilberns formation in the western and northern part of the Central Mineral region. These intraformational conglomerates are very attractive with flat pebbles of many colors stacked in odd arrangements in a greenish glauconitic matrix. These beds are seldom more than a foot thick and are limited in areal extent.

The bottom limestone of the Wilberns formation (Morgan Creek limestone member) throughout its outcrop area contains gray bedded marbles. The beds are mostly thin, seldom being more than 2 feet thick. The marble is mostly clear gray, sprinkled with green glauconite.

The minerals of the Wilberns marbles are chiefly calcite and some dolomite. Glauconite is present in the edgewise conglomerates and the gray basal marbles and is absent in the reef and *Girvanella* marbles. A minor amount of extremely small quartz grains was found in about one-third of the marbles examined. The edgewise conglomerates contain considerable quartz, and some feldspar, biotite, and muscovite. Some outcrops of the Wilberns formation in Gillespie County are shown in figures 3, 11, 13, and 14.

The Ellenburger marbles are divided into two groups depending upon the preponderance of calcite or dolomite. The calcite marbles are extremely fine-grained dense marbles which take a very high polish. Of the 23 calcite marbles described, 2 contain a minute number of very small quartz grains. Most of the calcite marbles contain a small amount of dolomite concentrated chiefly along stylolites. The 23 localities mentioned are situated in Burnet, Gillespie, Llano, and San Saba counties. Many other localities in these counties are not described, and many additional localities are present in Mason, Blanco, McCulloch, and Lampasas counties. Detailed mapping of these counties will outline outcrop areas of Ellenburger marbles. Mapping of Gillespie County is complete, except for dividing the Ellenburger in the eastern part of the county, and the mapping of Blanco County is nearing completion. Some outcrop areas of these marbles are shown in figures 3, 11, and 13.

Calcite marbles are present at several horizons in the Ellenburger. The basal mostly non-cherty member, the Threadgill (fig. 13), is thin bedded limestone throughout much of the southern and western part of the outcrop area. The limestones in the upper portion of the Ellenburger vary much in chert content, some being free of chert and others crowded with chert.

The dolomite marbles are microgranular to coarse grained and do not take a brilliant polish. Out of 17 samples examined, 9 are composed essentially of dolomite, 5 contain some calcite, 4 contain minor amounts of small detrital quartz grains, 2 contain glauconite, and 1 contains a small amount of detrital feldspar. The dolomites described are from Blanco, Burnet, Gillespie, and San Saba counties. Many other areas of dolomite are present in these counties and also in Llano, Mason, and McCulloch counties.

The Cambrian Pedernales dolomite member of the Wilberns formation is present in the eastern and northern part of the outcrop area and is absent in the western and southern part of the area. It is equivalent to the San Saba limestone member of the Wilberns formation and grades laterally into it westward. The Pedernales dolomite member of the Wilberns formation is almost chert free in many places and in part is fine grained and in part coarse grained. The fine-grained portion is predominantly yellowish gray to silvery gray. The dolomite of the Threadgill member of the Tanyard formation is mostly coarse-grained, non-cherty, and very similar to the coarse-grained Pedernales dolomite. The dolomite in the Staendebach member of the Tanyard formation contains abundant chert and is mostly fine to medium grained. The dolomitic lower portion of the Gorman formation is mostly microgranular and variegated. Dolomite beds are present throughout most of the rest of the Gorman formation and the Honeycut formation and are mostly microgranular to fine grained and occasionally medium grained. Of these dolomites those contained in the dolomitic facies of the Gorman formation are the most attractive stone. The coarse-grained dolomites of the Pedernales and Threadgill members are massive but probably will be little used as building stone.

The Chappel limestone of Mississippian age outcrops intermittently throughout the region, and many of the outcrops are a foot or less in thickness and others, mostly in structural sinks, may be as much as 40 or 50 feet thick. The Chappel limestone was not sampled. Limestone in the Barnett formation of Mason County is predominantly a crinoid stem breccia of light color.

The Marble Falls limestone is divided by Plummer[62] into four members. The bottom member, Gibbons conglomerate, is insignificant. The next member, the Sloan, is a dark-colored limestone, being brown, black, or combinations of those colors. The Big Saline member has some very attractive gray limestone in it. The top member, the Lemons Bluff, is crowded with sponge spicules which remain as a pulverulent porous mass after the calcite is removed by weathering. The tripoli deposit about 4 miles southwest of Lampasas is of this type. Other siliceous residues, tough and compact, yet highly porous, are present in western San Saba County. This rock is locally called cotton rock and has been used for local building, especially for chimneys.

The location of the following described deposits are shown in Plate 1.

Cambrian Cap Mountain Marbles

Description by Localities

Blanco County

LOCALITY BL–12

Location and geology.—A deposit of Cap Mountain limestone is located 9 miles northwest of Johnson City on the road to Sandy post office. The nearest railroad is at Marble Falls, a distance of 20 miles by road, 13 miles of which is hard surfaced and the rest of which is graded but not otherwise improved. A small amount of limestone has been quarried for local use. It is in beds about 6 inches thick and contains bright green glauconite and anastomosing tracings which might be filled burrows. One bed contains abundant *Acotreta*. A short distance to the east the limestone is down-faulted against Hickory sandstone. To the west at the foot of the hill the Cap Mountain limestone grades downward into Hickory sandstone.

Megascopic description.—The limestone is grayish brown with a slightly greenish cast. Filled burrows in it are light gray and produce a nice contrast with the darker colored stone. Fossil fragments are rather abundant. Glauconite is sparingly distributed throughout the stone and pyrite is present as small crystals. The limestone takes a fair polish and is classified commercially as a marble.

Recommendations.—The limestone is of value only for rough stone for local building. The deposit is too small and too thin bedded for commercial production and is also far from a railroad.

LOCALITY BL–26

A deposit of Cap Mountain limestone is located 7.25 miles from Johnson City on the road to Sandy post office. The nearest railroad is at Marble Falls, a distance of 22 miles by road, 13 miles of which is hard surfaced and the rest of which is graded but not otherwise improved. The limestone contains an occasional grain of glauconite and some trilobite fragments. It dips about 5° to the southeast. The beds are up to 10 inches in thickness, many being about 6 inches thick. Up-hill to the east more massive beds are exposed. Some of these beds contain rounded objects which may be *Girvanella*.

MISCELLANEOUS LOCALITIES

Most of the Paleozoic rocks of Blanco County were mapped during the spring of 1942. Locality Bl–26 is near the northeastern end of an outcrop area of the Cap

[62]Plummer, F. B., Stratigraphy of the Lower Pennsylvanian coral-bearing strata of Texas: Univ. Texas Pub. 4401, pp. 64–69, 1944 [1945].

Mountain limestone which extends about 6 miles to the southwest and is almost 2 miles wide. The continuity of outcrop is disturbed by one small fault. Sample Bl–12 is from the downthrown block and Bl–26 is from the upthrown block, but at a distance of 1.5 miles from the fault. The Cap Mountain limestone is well exposed in bluffs along Pedernales River, North Grape Creek, and Hickory Creek. An enormous amount of very massive limestone is exposed in situations ideally suited for quarrying but unfortunately much too far from a railroad.

Other important outcrop areas of the Cap Mountain limestone are situated in western and northwestern Blanco County. A fault block syncline 10 miles west-northwest of Round Mountain contains two important outcropping areas of Cap Mountain limestone. The southwestern limb of the syncline is trenched by White Creek and the northeastern one by the head drainage of Walnut Creek, furnishing excellent exposures. Another fault block syncline adjacent to and to the southwest of the one mentioned above has an important area of Cap Mountain limestone exposed on the southern limb trenched by the head drainage of Comanche Creek. The Cap Mountain limestone exposed in the northern limb of the syncline is narrow, dips steeply, and is highly faulted. Several other small fault blocks containing Cap Mountain limestone are located to the east of the first mentioned fault block syncline. An area of Cap Mountain limestone somewhat faulted is located along North Grape Creek 4 miles west of Sandy and extends in a north-south direction for about 4 miles. The upper portion of the Cap Mountain limestone outcrops in the crest of an anticline along Pedernales River and Iron Rock Creek. It extends from near McDougal's Crossing in Blanco County into Gillespie County. Several small fault blocks of Cap Mountain are exposed to the east of McDougal's Crossing.

Burnet County

LOCALITY BU–15

Location and geology.—A deposit of Cap Mountain limestone is located along the Burnet-Marble Falls highway at a point about 2 miles south of the railroad crossing near Sudduth. The limestone is grayish brown and is in beds up to 18 inches thick. It is in the upper portion of the Cap Mountain limestone and just below the Lion Mountain sandstone member. The total thickness of usable stone is probably in excess of 20 feet.

Megascopic description.—The limestone is dark colored and in color is a combination of dark greenish gray, dark brown, and a small amount of brown-tinted white. It is a bedded rock having somewhat the appearance of an intraformational conglomerate. Between the thin fragments of beds is a cemented fossil agglomerate. Glauconite is abundant. The limestone takes a fair polish and is therefore classified commercially as a marble. The glauconite polishes low, giving the surface a pitted appearance.

Microscopic description.—The limestone is composed largely of calcite and contains numerous glauconite and quartz grains and some feldspar, biotite, and muscovite grains up to 1 mm. in size. Numerous trilobite fragments are contained which appear in thin section as long undulating filaments, and some are apparently complete cross sections of trilobite heads. The mineral in these trilobite fragments is probably calcite, but even under high magnification the individual particles are not resolved. An unusual development of calcite has taken place with long bladed crystals of calcite extending outward perpendicular to the surfaces of the trilobite fragments. The bladed calcite may have been orginally aragonite. Quarter-inch areas in the thin sections appear to be filled burrows containing numerous brown plates of chitin or a related substance.

Recommendations. — Along Backbone Ridge similar stone is better situated for quarrying and nearer to the railroad; but this is a good deposit.

LOCALITY BU–22

Location and geology.—A bluff of Cap Mountain limestone is located at Hoover Point 1.5 miles southeast of Kingsland. The limestone forms a steep bluff about 100 feet above the railroad. The bed sampled is near the bottom of the massive limestone portion of the Cap Mountain limestone. The upper portion of the limestone forms a vertical bluff with scarcely any bedding joints. This is a desirable building stone and is also well located for producing crushed rock. A transmission line, a railroad, a serviceable county road, and Colorado River all pass within a few hundred yards of the deposit.

Megascopic description.—The limestone is predominantly a combination of ill-defined bands of brown, yellow, and gray colors. Stylolites are commonly the demarcation line between different colors. The limestone is composed of closely packed oolites and some pisolites ranging up to one-fourth of an inch in size. A few fossils are visible and some glauconite is present. The limestone takes a fair polish and is classified commercially as a marble.

Microscopic description.—The limestone is composed largely of calcite and contains numerous ½ to 1½ mm.-sized spherical areas of limonite-stained calcite. A few grains of glauconite of the same size and shape are present, suggesting that the limonitic areas are altered glauconite grains. These grains have some concentric structure brought out by the alteration. Some leaching of limonite has apparently taken place as evidenced by a series of spherical areas that can be chosen which range from a solid limonitic color to spherical areas without any limonitic color. These latter areas have a radial or concentric structure which differentiates them from the surrounding calcite. Angular quartz grains up to one-fifth of a millimeter in size are rather common.

Recommendations.—The limestone is rather dark colored but could be used for some ornamental trims and as a building stone. Crushed it is excellent for aggregate and terrazzo chips. It is the best located Cap Mountain limestone deposit in the uplift. It has a railroad, power line, the Colorado River, and a serviceable county road all within a few hundred feet of it.

LOCALITY BU–26

Cap Mountain limestone is located about 1 mile north of the railroad north of Fairland. It is west of the old Marble Falls-Burnet road at a point where an abandoned road approaches the top of a steep slope. The limestone is from the upper portion of the Cap Mountain formation which is composed of massive beds up to as much as 2 feet in thickness. The bed sampled is about 1 foot thick and is the uppermost bed exposed.

The limestone in color is a combination of shades of grayish brown and a few small areas of white. Stylolites are present but are not distinct. The limestone is composed largely of oolites and a very small amount of glauconite. A few rounded objects may be small *Girvanella.* The limestone takes a fair polish and is classified commercially as a marble. A large amount is present and it appears to be of good quality. The color is somewhat dark but the stone should find many applications in building.

Cambrian Wilberns Marble

Description by Localities

Blanco County

LOCALITY BL–21

Location and geology.—A deposit of the Morgan Creek limestone member of the Wilberns formation is located 5.5 miles west of Round Mountain on the graded Round Mountain-Llano road. The distance from Round Mountain by hard-surfaced highway to the nearest railroad, which is at Marble Falls, is 11 miles. A bed of good gray limestone 1 to 2 feet thick is exposed along the road. It has transparent streaks and some green lines in it. The limestone dips gently to the southwest.

Megascopic description.—The limestone is a combination of a wide range of pastel shades dominated by pinks, purples, yellows, and ivories. The limestone is composed of small elongated fragments mostly parallel to the bedding, but a few stand at sharp angles to the bedding. These fragments are mostly embedded in a clear calcite which makes them stand out distinctly. A few stylolites and faults of small displacement lend further character to the stone. An occasional filled burrow of a drab brownish gray does not detract from the pleasing appearance of the stone. The limestone takes a brilliant mirror-like polish and is classified commercially as a marble.

Microscopic description.—The limestone is composed predominantly of calcite, which is about equally divided between areas of a very cloudy fine-grained calcite and a surrounding network of coarse-grained calcite ranging up to about 3 mm. in grain size. The fine-grained calcite areas are predominantly rounded, a few have radial structure, and a few have an indistinct concentric structure suggestive of oolites. Some of these areas contain somewhat clouded dolomite rhombs in which the inclusions are mostly concentrated as a band a short distance from the edge of the rhombs. These areas also contain a few fossil remnants.

Recommendations.—The stone is very attractive and should be of value as a decorative and ornamental stone. The zone is not very thick but is exposed along its outcrop for at least a mile, making a large amount of stone available.

MISCELLANEOUS LOCALITIES

The Morgan Creek limestone member of the Wilberns formation is much better exposed in many other portions of Blanco County. It parallels all the Cap Mountain limestone outcrops described on page 131. It is well exposed along White Creek, the head drainage of Comanche Creek, North Grape Creek, and three complete sections are exposed along Pedernales River. The following section was measured on the Scott Klett ranch 5 miles airline distance west of Johnson City.

Section of Cambrian rocks exposed on Scott Klett ranch 5 miles airline distance west of Johnson City, Blanco County.

	Thickness Feet
Travis Peak sand.	
Unconformity	
Cambrian system—	
Wilberns formation—	
Pedernales dolomite member—	
Massive indistinctly bedded dolomite	41.4
Thickly bedded dolomite	23.1
Thinly bedded dolomite	12.2
Point Peak shale member (?)—	
Shaly dolomite	14.4
Stromatolite limestone	11.2
Morgan Creek limestone member—	
Brownish-gray limestone containing silicified *Billingsella*	2.7
Stromatolite limestone	1.3
Gray limestone	6.8
Stromatolite limestone	1.5
Gray limestone	6.8
Stromatolite limestone	1.5
Gray limestone	6.2
Stromatolite limestone	1.8
Gray limestone	11.9
Shaly limestone	7.4
Gray limestone with scattered stromatolites in lower part	15.5
Stromatolite limestone	2.5
Gray limestone	11.2
Shale	3.0
Gray limestone	13.3
Oolitic limestone	7.5
Edgewise conglomerate interspersed with stromatolites	0.8
Gray limestone	6.7
Oolitic limestone	1.2
Gray limestone with mud-ball bed 3 feet from bottom	13.6
Oolitic limestone	0.5
Gray limestone	3.2
Reddish sandy limestone	11.3
Welge sandstone member—	
Brown sandstone	10.0
Disconformity	
Riley formation—	
Lion Mountain sandstone member—	
Greensand	25
Cap Mountain limestone member—	
Thin-bedded, lenticular, glauconitic, *Aphelaspis*-bearing limestone	10
Brown, thick-bedded limestone	18
Bottom of section at river level.	

The above section demonstrates the varied character of the Morgan Creek limestone member of the Wilberns. Some sections are practically devoid of the stromatolite limestones and others contain more. The oolitic limestone is missing in most sections and edgewise conglomerate is rare. Shaly limestone is absent in some sections and more abundant in others.

Burnet County

LOCALITY BU-21

Location and geology.—A deposit of stromatolite marble in the Point Peak shale member of the Wilberns formation is located 4.7 miles by road northeast of the railroad at a point about 1 mile east of Kingsland. The stromatolite marble is in a fault block alongside a large graben of Paleozoic rocks, and the recently constructed Longhorn Cavern-Inks Dam road exposes it very well. It is about 10 feet thick and dips into the hillside. A large fault to the east drops the Honeycut formation against the Wilberns formation, and numerous small faults and joints formed at the same time have broken the reef into rather small blocks. A short distance above the stromatolite marble 20 to 30 feet of *Girvanella* limestone is well exposed.

Megascopic description.—The stromatolite marble is intricately mottled with abundant irregular areas of grayish buff scattered throughout a background of white to grayish white. Stylolites are rather widely spaced and are mostly yellow-brown in color. The marble takes a good polish.

Microscopic description.—The stromatolite marble is composed almost entirely of dolomite grains and rhombs ranging up to one-third of a millimeter in size. Mostly, however, the grain size is much smaller. Areas of different grain size give the thin section a faintly mottled appearance. No mineral other than dolomite was recognized; however, very minute inclusions are present in the dolomite grains.

Recommendations. — The stromatolite marble is attractive, but this particular deposit is poorly situated to be quarried. Many other deposits along the south side of Backbone Ridge are better located and under less cover.

LOCALITY BU–27

Location and geology.—A deposit of stromatolite marble in the Point Peak shale member of the Wilberns formation is located about 1.3 miles north of the railroad north of Fairland in and to the east of the old Marble Falls-Burnet road. The marble is estimated to be about 5 feet thick. It is mostly on a dip slope without a good cross section exposure and is about 20 feet above the *Eoorthis remnichia* subzone of the Wilberns.

Megascopic description.—The marble is mottled with irregularly shaped brown areas abundantly scattered throughout a greenish-tan groundmass. Stylolites are present but are somewhat obscured by the abundant mottling. The groundmass contains some fossil fragments. The marble takes a fair polish interrupted to some extent by the stylolites which polish low. It is classified as a marble.

Microscopic description.—The marble is composed predominantly of calcite and some dolomite. Some angular quartz grains up to one-fifteenth of a millimeter in size are present. The dolomite is in rhombs about one-fourth of a millimeter in size and is stained yellow throughout. The calcite is of about the same grain size with a few grains in veins as much as 2 mm. in size. Most of the calcite and dolomite is highly clouded by very fine inclusions.

Recommendations.—The marble is well situated with little overburden and could be easily quarried. It is also along a road and near to railroad transportation.

LOCALITY BU–28

A deposit of stromatolite marble in the Point Peak shale member of the Wilberns formation is located along the Longhorn Cavern road about 3.5 miles west of the railroad, at a point about 5 miles south of Burnet. The marble is about 5 feet thick, has a gray color with a greenish cast and is mottled to some extent with light ivory-colored areas and hackly yellowish-brown areas. Stylolites are well developed and quite irregular in trend. The marble takes a brilliant mirror-like polish except along the stylolites which polish low. The marble was not thin sectioned, but a staining test reveals that it is composed entirely of calcite. At the outcrops the stromatolite "heads" are not well joined, indicating that large pieces of marble could not be produced. Better deposits can be found in the area. Aerial photographs of this portion of Burnet County reveal numerous beds of stromatolite marbles that can be traced for miles. As yet these have not been mapped, and they have been seen only along the Burne'-Marble Falls highway.

Cillespie County

LOCALITIES G–19 AND G–20

Location and geology.—A deposit of limestone in the Wilberns formation in the bed and along the banks of Pedernales River at Blumenthal, is beneath the Pedernales dolomite described on pages 153–

154. A map of a small area in this vicinity is shown in figure 14.

The marble in part is massive stromatolite limestone and in part is bedded and somewhat dolomitic. The lower part of the deposit is massive and the upper part is thin bedded. Cretaceous conglomerate outcrops 500 feet downstream, and Travis Peak sands surround the outcrop on both sides of the river. The entire outcrop is below high water mark. Similar marbles are present 1 mile to the northeast in outcrops which are favorably situated for quarrying.

Megascopic description.—The marble varies in color and texture from bed to bed. One polished sample (G–19) from a bed 20 inches thick is a rather pleasing combination of greenish gray with stylolite lines of dull purple and areas having a faint purplish tint. The rock is crowded with small fragments of fossils which are essentially white. Small cavities are numerous and the rock takes a rather good but somewhat uneven polish.

Another bed 2 feet thick (G–20) which is several feet above the bed just described is predominantly brownish red. Small ivory-colored and minute white areas, none of which is more than one-fourth of an inch in size, have a random distribution. Stylolites are present but are very inconspicuous. The marble takes a brilliant polish.

Microscopic description.—Sample G–19 is composed of about equal proportions of dolomite and calcite. Some of the calcite is exceedingly fine grained and some is coarsely granular ranging up to 3 mm.-sized grains. The dolomite is more nearly equigranular and averages about one-third of a millimeter in grain size. The two minerals tend to be segregated, but some perfect rhombs of dolomite have developed in the fine-grained calcite. The fine-grained calcite also has many fossil remnants in it. A small amount of angular quartz up to one-tenth of a millimeter in grain size is present.

Sample G–20 is composed of about one-third calcite and two-thirds dolomite. The calcite is in 1 to 3 mm.-sized grains and contains innumerable small inclusions which are somewhat more concentrated in the centers than at the edges of the grains. The dolomite is in grains and rhombs of about one-third of a millimeter in size. A very small amount of angular quartz mostly less than one-fifteenth of a millimeter in size is present. By reflected light considerable reddish cloudy material is seen situated along grain boundaries.

Recommendations.—The deposit is in the bed of Pedernales River and could not be quarried. Similar stone above river level is located 1 mile to the northeast. The stone is attractive, is of good quality, and is of value as a building and ornamental stone.

Llano County

LOCALITY LL–60

Location and geology.—*Girvanella* limestone of the San Saba limestone member of the Wilberns formation is located just north of Point Peak and at a distance of 5.7 miles by road from Lone Grove, which is about 2 miles north of the railroad. The *Girvanella* limestone is well exposed in road cuts and along the creek just to the west of the road. It is mostly light buff and contains white *Girvanella* the size of marbles. The *Girvanella* are much more numerous in some beds than in others. The beds dip very gently northward and are at least a hundred feet thick. A 5-foot zone having an attractive pink color is located near the top of the *Girvanella* beds. A portion of the deposit is composed of beds averaging 4 inches in thickness, which could be used for flagging. Massive beds 5 to 6 feet thick, suitable for producing saw blocks, are exposed in a 25-foot bluff on the western side of the creek.

Megascopic description.—The marble is chiefly a combination of irregular color zones of ivory and yellow with some translucent gray-brown zones. The distinctive feature of the marble is abundant, very light-colored, spherical *Girvanella* ranging between about one-fourth to one-half of an inch in size. The yellow bands take very little polish, while the rest of the rock takes a brilliant mirror-like polish. The yellow bands upon heat treatment change to a very attractive red, which is possibly more attractive than the natural color.

Microscopic description.—The marble is composed predominantly of calcite with some thin yellow seams composed predominantly of fine-grained dolomite. The texture of the *Girvanella* is very little different from that of the matrix except that they contain no fossil fragments. The matrix contains some fossil remnants, is predominantly fine grained, and varies somewhat in texture.

Recommendations. — *Girvanella* limestone finished pitched face was used in the old Cherokee College building at Cherokee. The building is very attractive and is an example of one good use for *Girvanella* limestone. The *Girvanella* beds of the Point Peak area are better developed than elsewhere in the uplift and this attractive stone should be produced.

Mason County

LOCALITY M–21

Location and geology.—A small deposit of stromatolite limestone in the Wilberns formation is located about 1 mile north of the Mason-Gillespie County line and about one-third of a mile west of the Mason-Fredericksburg highway. The deposit is 19 miles from Fredericksburg. A map of a small area in the vicinity of the deposit is shown in figure 15. Only the major faults are shown.

An attempt was made to quarry the stone at the southern quarry symbol shown in figure 15. The stone is highly faulted and saw blocks of sound stone could not be produced.

A north-south trending major fault 400 feet to the east dropped the Wilberns formation against Hickory sandstone. The Wilberns formation for a considerable distance to the west of this fault has been minutely sliced by faults of small displacement. Stromatolite limestone of the same type but not faulted is present on Squaw Creek a few miles to the west (fig. 13). The Squaw Creek area is described on page 128. A cavern disclosed by the quarry contains a deposit of onyx marble, described on page 177.

Megascopic description.—The marble is ivory-colored with bright yellow areas and greenish-gray stylolites. It resembles a breccia or an edgewise conglomerate, and many of the stylolites are open. The marble takes a brilliant mirror-like polish.

Microscopic description.—The marble is composed predominantly of calcite, most of which is fine grained and cloudy. The fine-grained calcite is surrounded by a network of clear coarse-grained calcite. Several fossil remnants are present. The stylolites in thin section are tight with only a trace of yellowish cloudy material along them.

Recommendations.—The stone is very attractive but cannot be successfully quarried at this locality. Large deposits of stromatolite limestone are located along Squaw Creek where large quarries could be established.

San Saba County

LOCALITY S–12

Location and geology.—A *Girvanella* limestone of Wilberns age is located 1 mile west of the Cherokee-San Saba road at a point about 1.8 miles north of Cherokee. It is located about 15 miles from the railroad at San Saba. The limestone used in the construction of Cherokee College was obtained from this locality. A section of Wilberns along the highway possibly as much as 50 feet thick has numerous beds of *Girvanella* limestone in it, some of which are up to 2 feet in thickness.

Megascopic description.—The marble is predominantly of a dark ivory color and contains abundant *Girvanella* which are of a translucent gray-buff color. The *Girvanella* are in marked contrast with the rest of the rock. Stylolites are well developed. The presence of stylolites and spherical *Girvanella* furnishes incontrovertible evidence supporting the solution-pressure theory of the origin of stylolites, which recently has been attacked by Shaub.[63] *Girvanella* are of spherical shape and usually do not occur as fragments; consequently, when they are situated along stylolites and portions are missing it must be assumed that these portions have been removed by solution. Many perfect examples of penetration of *Girvanella* by stylolite columns are present in the *Girvanella* beds. All gradations may be found

[63]Shaub, B. M., The origin of stylolites: Jour. Sed. Petrology, vol. 9, pp. 47–61, 1939.

between *Girvanella* barely attacked by solution and those which are all but consumed. As would be expected, solution has taken place on both sides of the stylolites, as evidenced by partly destroyed *Girvanella* both above and below stylolites. The marble takes an excellent mirror-like polish interrupted only by somewhat open stylolite lines.

Microscopic description.—The marble is composed of extremely fine-grained calcite which contains abundant fossil remnants of several types. The *Girvanella* are somewhat more coarsely crystalline but reveal very little evidence of structure. They are, however, free of fossil remnants. A very small amount of angular quartz and a few small specks of glauconite are contained in the matrix.

Recommendations.—The *Girvanella* limestone is an exceptionally attractive building stone. The beds in this vicinity are rather thin and can be used mostly for pitched face building stone. In other localities where the beds are thick the stone is of value for producing large polished slabs for interior use.

LOCALITY S–13

Location and geology.—A deposit of edgewise conglomerate in the Point Peak shale member of the Wilberns formation is located about 26 miles by road south-southwest of Harkeyville, which is the nearest point on a railroad to the deposit. The road is graded for 25 miles of the distance but is otherwise unimproved. The deposit is located about one-half mile north of the Taylor ranch house along Deep Creek. The edgewise conglomerate is in a layer about 10 inches thick and is exposed on the creek bottom. The deposit is small with most of the conglomerate outcropping along the hillside to the east of the creek. Above the conglomerate bioherms of stromatolite limestone 10 feet thick and up to 30 feet long are exposed in the creek bank. To the west of the creek a large expanse of stromatolite limestone is exposed. Several layers of edgewise conglomerate are located upstream to the south.

Megascopic description.—The edgewise conglomerate is an intraformational conglomerate composed of pebbles many times as long and wide as they are thick. One pebble contains smaller pebbles of the same type, indicating that the sea bottom was periodically disrupted by storms. Lithification was sufficient so that conglomerate formed during one storm would be ripped up during succeeding storms without being disintegrated. The pebbles are predominantly gray with a greenish tint and contrast strongly with the matrix which is a brownish gray. The matrix is a well-cemented mixture of small fragments having the same composition as the pebbles and fossil fragments. Some of the light-colored pebbles are limonite stained and some are color banded. The matrix takes a good polish and the pebbles remain dull.

Microscopic description.—The edgewise conglomerate is composed predominantly of calcite. It also contains considerable fine-grained quartz, feldspar, biotite, and muscovite. Some of the biotite is altered in part and some wholly to a green mineral having high birefringence. No evidence was seen that there is a further change of this material to glauconite. Several portions of edgewise pebbles are included in the thin sections. They are invariably of different texture than the matrix surrounding them. Some of these pebbles are composed of rather dark fine-grained calcite, and others are an agglomeration of all the minerals recognized in the thin section. The matrix is relatively free of minerals other than calcite but contains abundant trilobite fragments.

Recommendations.—The deposit sampled is small. However, numerous exposures of edgewise conglomerate are present in the area and sufficient may be found to warrant production.

Cambrian and Ordovician Marbles

CALCITE MARBLES

Description by Localities

Burnet County

LOCALITY BU–11

Location and geology.—A deposit of Ellenburger marble is located 2 miles by road south of Burnet and just west of the road to Morman Mills. The road to Burnet is graded but not otherwise improved. The deposit is about one-half mile east of a railroad. A pace-compass map, figure 16, was made of the outcrop during a Work Projects Administration mineral resource survey of Burnet County, sponsored by the Bureau of Economic Geology of The University of Texas. The outcrop which dips gently northward is a dip slope having a slope of about 20 feet in 600 feet. It is about 600 by 1700 feet in size and the entire outcrop, except for a small area at the eastern end, is composed of uniform-textured, chert-free calcite marble with widely spaced joints. A small amount of chert is present in a limited area at the eastern end of the outcrop.

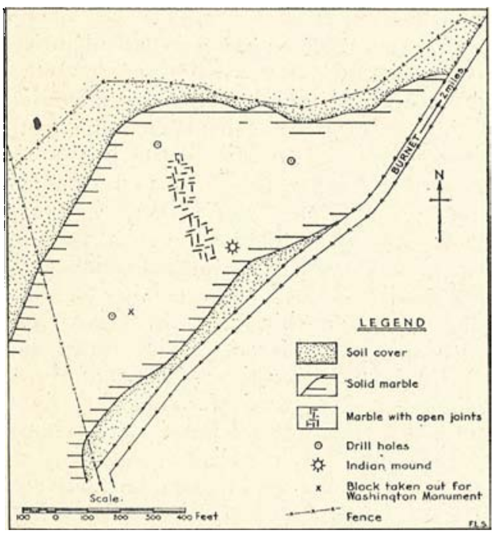

Fig. 16. Outcrop map of marble 2 miles south of Burnet, Burnet County, Texas.

A small area outlined in the central part of figure 16 is entirely free of soil, and solution along joints has produced openings 6 or more feet in depth. The marble varies somewhat in color between white and a light beige. Much of it has delicate red lines and stylolite markings. In some of the stone the markings are purple. A block of stone was taken from this deposit as the Texas contribution to the Washington Monument.

At the northern side of the deposit past the outcrop area, trenching revealed some unusually large blocks of stone without joints. In an east-west trench one block was found which is 47 feet across and at least 57 feet in a north-south direction. The north-south trench was not carried to the northern edge of the block. The outcrop area extends for an unknown distance to the west. To the north the marble may continue for a considerable distance but is covered by soil and overburden of unknown thickness.

Megascopic description.—Some of the marble is ivory-colored with exceedingly thin stylolite lines of white and delicate shell-pink. At the southern side of the deposit a drill core reveals that the marble is brecciated with veins of white and colorless calcite and dark red lines. The breccia fragments have a very faint purplish cast, their basic color being a deep ivory. The marble takes a very brilliant mirror-like polish and is classified commercially as a marble.

Microscopic description.—The marble is composed of extremely fine-grained calcite with an occasional veinlet of coarse-grained calcite cutting it. Some stylolites are present which are slightly brownish by transmitted light and are cloudy and white by reflected light. The marble contains no recognizable mineral other than calcite. One veinlet crossed a stylolite and another was terminated by a stylolite, indicating that these veinlets probably formed during a considerable range of time.

Recommendations.—The marble is of a very attractive color and takes an extremely high polish. A large amount of marble situated in a favorable position for quarrying and near to railroad transportation exists in this area. The marble is of value as a building and ornamental stone.

LOCALITY BU–16

Location and geology.—A deposit of marble is located along Honey Creek on both sides of the railroad and the hard-surfaced Burnet-Marble Falls highway at a point 2 miles north of Sudduth. A massive 5-foot ledge of red-lined marble is exposed on the south bank of Honey Creek just west of the highway. An 8-foot massive ledge of similarly colored marble is exposed along Honey Creek just east of the railroad. The bed extends east of the road for about one-half mile and to the west for about 200 yards. It varies widely in thickness and is a stromatolite marble either in the Threadgill member of the Tanyard formation or is San Saba limestone surrounded by Pedernales dolomite.

Megascopic description.—The marble varies in color. Some of it is light gray with delicate tints of lavender. The stylolites are darker gray and have dolomite concentrated along them. In some of the stone the stylolites are red. The marble takes a brilliant mirror-like polish.

Microscopic description.—The marble is composed predominantly of fine-grained calcite having a range up to about one-fifth of a millimeter in size. Grains of different size are grouped, producing a mottled surface in thin section. Some dolomite with undulatory extinction is present in grains up to 3 mm. in size. The dolomite areas appear to be shear zones. A very small amount of a green mineral resembling glauconite is present.

Recommendations.—The marble is of excellent color and takes a mirror-like polish. It is located along a railroad and highway. Some drilling would be needed to outline the extent of the deposit. The marble is an excellent building and monumental stone.

LOCALITY BU–24

Location and geology.—A deposit of Ellenburger marble is located 3 miles by a hard-surfaced road west of Burnet. It is just southeast of a fault and a short distance east of the intersection of the new and old Llano-Burnet highways. A fault has dropped the marble against Hickory sandstone. The marble is probably from the Threadgill member of the Tanyard formation. Some sections of fossils are present on cut surfaces of this stone but none were seen which are diagnostic.

Megascopic description.—The marble is nicely colored in a wide range of pastel shades of browns, reds, and faint yellows on a background of light ivory. A small amount of white coarsely crystalline calcite is also present. The colors are confined mostly to the stylolites which are very abundant and very irregular. The stylolites coalesce to form isolated areas of light ivory-colored stone. These areas contain some fossil material. The marble takes an excellent mirror-like polish only slightly interrupted by the stylolites.

Microscopic description.—The marble is composed almost entirely of calcite. Much of it is in grains 1/30 of a millimeter or less in size; however, there are substantial numbers of grains of larger size, mostly in groups, which range up to 3 mm. in size. No mineral other than calcite was recognized, and only a very small amount of included material is present in the calcite. A staining test shows that dolomite is concentrated along the stylolites.

Recommendations.—The marble is very attractive. Insufficient mapping has been done to outline its extent, and drilling would probably be necessary to ascertain the thickness of good stone. The marble, if present in sufficient quantity, is of value as an ornamental building stone.

LOCALITY BU–25

Location and geology.—A deposit of Ellenburger marble is located 5 miles west of Burnet and about 1 mile west of the Burnet-Kingsland road. The road for half the distance is hard surfaced, for 1.5 miles is graded, and for the other mile is an unimproved pasture road. A fault trends N. 45° W., dropping calcite marble on the southeast against dolomite to the northwest. The marble is exposed over an area of about two acres and appears to be a massive sound stone. No chert was seen, indicating that the marble may be in the Threadgill member of the Tanyard formation.

Megascopic description.—The marble is lavender of varying intensity crossed by stylolites along which several colors are present, including an intense lavender approaching purple and several shades of golden brown. A few white calcite veins are present. The marble takes an excellent polish.

Microscopic description.—The marble is composed predominantly of very fine-grained calcite and some veinlets of coarse-grained calcite. Shell fragments are plentiful, and slightly dark rounded areas have coarser grained calcite around them. No mineral other than calcite was recognized; however, some minute inclusions are present in the calcite.

Recommendations.—The marble is very attractive. It outcrops over about two acres and may outcrop elsewhere along the fault. It appears to be thick but should be drilled to prove definitely its thickness. The marble is of value as an ornamental building stone.

LOCALITY BU-29

Location and geology.—A sample of Ellenburger calcite marble was obtained on a vacant lot in the southwestern part of Burnet. The outcrop is extremely limited in area, but the amount of stone beneath the soil covering may be large. One section of a gastropod resembling *Gasconadia* is present on a polished surface, suggesting that this marble may be from the Threadgill member of the Tanyard formation.

Megascopic description.—The marble has a background varying from ivory to buff, interrupted by a variety of colors and designs. Lines of red color produce varied figures and give the stone a very attractive appearance. Coarsely crystalline white dolomite areas in the marble are invariably bordered by a narrow band of yellow. Stylolites are distinguished by a similar yellow banding. The marble takes an excellent polish only slightly interrupted by the dolomite areas.

Microscopic description.—The marble was not thin sectioned, but a staining test reveals that it is composed predominantly of calcite with dolomite concentrated along stylolites.

Recommendations.—The marble is extremely attractive but is situated in Burnet and the outcrop is small. It is unlikely that a quarry could be developed at this locality.

LOCALITY BU-31

A calcite marble deposit in the Honeycut formation is located 2 miles by road south of Marble Falls along Flatrock Creek just north of the Marble Falls-Spicewood road. The marble outcrops along Flatrock Creek for half a mile or more. Near the road it contains some dolomite beds and some chert. Downstream at the first bend the calcite marble is chert free.

The marble is mostly ivory-colored with some areas which are tinted slightly gray. The polished specimen contains narrow seams of a yellow to deep yellow-brown color. Numerous pin point-sized pits on the polished surface appear to be hollow dolomite rhombs. The marble takes an excellent polish. The marble was not thin sectioned, but a staining test reveals that it is predominantly calcite with a few pin point-sized specks of dolomite scattered throughout.

The marble is of a good color and takes an excellent polish. It is rather thin bedded and is probably mostly of value for pitched face stone.

LOCALITY BU-33

Location and geology.—A deposit of Ellenburger calcite marble is located along Hamilton Creek about 1.5 miles by road northwest of Burnet. The marble has been used for terrazzo chips and extends downstream from the pit for more than a quarter of a mile. The marble is of an ivory color marked by thin yellow seams. Several discontinuous beds of dolomite are located at creek level. Along the hillside to the east of the creek, boulders of calcite marble are abundant over a wide area. This outcrop contains no dolomite and only a minor amount of chert.

Megascopic description.—The marble is light colored with a background ranging from light cream to grayish buff which is irregularly distributed, producing a cloudy effect. Narrow yellow seams traverse the marble, and a few small areas of light green and white are present. The white areas are somewhat porous aggregates of dolomite crystals. A few fossil fragments are present. The marble takes a brilliant mirror-like polish.

Microscopic description.—The marble is composed almost entirely of calcite, mostly as very fine-grained areas surrounded by a network of clear calcite crystals ranging up to about one-half of a millimeter in size. Inclusions in the calcite are very scarce. A staining test reveals a few areas of dolomite.

Recommendations.—The marble east of the creek is beautiful but poorly exposed, and core drilling would be necessary to determine the amount present. The marble is of value as an ornamental building stone, and some of it has been used for terrazzo chips.

LOCALITY BU–37

A calcite marble sample was collected from the upper massive limestone of the Gorman formation a few hundred yards north of the present Longhorn Cavern entrance and from directly above a portion of the cavern. The deposit is located about 6 miles west of the railroad at a point 5 miles south of Burnet. Beds of marble up to 4 feet thick are present. Many solution channels have developed along joints, and locally the stone could not be utilized. Away from the cavernous areas the marble is massive. Abundant closely coiled gastropods in the marble enhance its beauty.

The marble is yellowish brown with areas of light gray following some of the stylolites. The yellowish-brown color varies in intensity, producing a nicely marked stone. Stylolites are rather abundant and are tight. Fossils are present which are attractive in polished sections. The marble takes an excellent polish. A large amount of attractive marble in this area cannot be produced because of its location within the Longhorn Cavern Park area.

LOCALITY BU–38

A deposit of marble located west of the Burnet-Marble Falls highway about 1 mile south of Burnet is exposed as large flat surfaces in a pasture about one-quarter of a mile from the highway. The marble has pink lines in it and is a very attractive stone. To the north of this locality is some pink dolomite which has been used for terrazzo chips. Mapping done during June, 1943, shows that the calcite marbles of this area are in discontinuous beds which are mostly thin.

The marble is ivory-colored with enough variation in color to produce a slightly mottled appearance. It is nicely marked by coral and red-colored lines, and a few small areas of colorless to white calcite are present. A few small white dolomite areas in the stone are outlined by narrow coral-colored bands. The color markings are situated mostly along stylolites, which can scarcely be detected except where color differences exist. The marble takes an excellent polish. The marble is poorly exposed and core drilling would be necessary to determine the amount present. It is a beautiful stone which takes a high polish and is a desirable building and ornamental stone.

LOCALITY BU–40

Location and geology.—A deposit of calcite marble located 2 miles west of the railroad at a point 5 miles south of Burnet is just south of the Longhorn Cavern road. The marble is exposed along a gently sloping hillside and outcrops in a direction S. 70° E. for a distance of at least 1500 feet. Coarse-grained, somewhat cherty dolomite underlies it and the top of the marble is poorly exposed. The end of the outcrop nearest the road is faulted against the Wilberns formation, and a swale with few outcrops follows the bottom of the marble along its trend. The marble is on a dip slope and is apparently thin. A few fossils, mostly gastropods, can be seen on some of the smooth, clean marble surfaces. The marble is mostly a stromatolite limestone and could be either San Saba limestone within the Pedernales dolomite or limestone in the Threadgill member of the Tanyard formation.

Megascopic description.—The marble is ivory-colored with light yellow markings along the stylolites, which are not so very abundant. It is uniform in texture and color except for the stylolite markings. The stylolites are tight and in places could not be recognized if it were not for their color. The marble takes an excellent polish.

Microscopic description.—Calcite is the only mineral recognized in the marble, which is composed of radial spherulites and rounded areas of cloudy calcite with some clear calcite crystals interspersed among the rounded forms. The central portion of some spherulites is cloudy, thus producing an ill-defined concentric structure. Radial calcite of adjoining spherulites in most cases completely occupies the intervening areas, giving these bodies a polygonal outline in thin section rather than a spherical outline. The radial bodies are mostly less than a millimeter in size, *Recommendations.*—The marble is attractive and of value as an ornamental building stone providing it is thick enough to be produced. This could be determined only by drilling.

LOCALITY BU–42

Location and geology.—A deposit of calcite marble in the uppermost limestone of the Gorman formation is located 0.4 mile north of Longhorn Cavern and about 6.5 miles west of the railroad at a point about 5 miles south of Burnet. The main outcrop of the marble is said to be directly above a portion of the Longhorn Cavern. It outcrops for a distance of about 500 yards. The outcrop is in part exposed by wide solution joints. The depth of these openings is about 15 feet, and the top bed as exposed is about 10 feet thick. Bordering the main solution joint to the west the marble is practically free of joints and openings. On the other side of the main solution joint the marble is traversed by solution caverns. The color of the marble is deep cream with faint pink and purple markings. Barely discernible on these outcrops is a polygonal marking brought out by a slight difference in texture of the inch-wide bands separating the polygonal blocks. The polygonal pattern is very similar to that present in some of the Wilberns stromatolite limestones and suggests that this marble may be of similar origin. Just above the marble is a cherty dolomite of the Honeycut formation, the chert of which contains abundant silicified brachiopods and gastropods.

Microscopic description.—The marble was not thin sectioned but from a staining test it is seen to be composed essentially of calcite. A short distance to the west a bed of white dense dolomite is exposed in which sand grains were detected. A thin section of the dolomite reveals that it is essentially composed of dolomite grains 1/10 of a millimeter in size. In about 1 square inch of thin section, about 2 dozen spherical grains of quartz are present ranging between about one-half and 1 mm. in size. These grains are exceptionally well rounded and under a hand lens appear to be frosted.

Recommendations.—The marble is of an excellent color and takes an excellent polish. The physical properties indicate that this is a sound marble which will be durable. A large amount of marble is exposed at the surface in an area which is favorable for establishing a quarry. This is an excellent building and ornamental stone.

Gillespie County

LOCALITIES G–22 AND G–23

Location and geology.—An Ellenburger marble deposit is located about 18.5 miles by road from Fredericksburg and about 5 miles east of Willow City. The marble outcrops in Willow Creek east of the Young ranch road. The beds strike east-west and dip 10° to the south. The main outcrop is calcite marble in beds averaging about 10 inches in thickness. Some beds contain numerous filled burrows and others are massive uniform-textured marble. Downstream and higher in the section a few dolomite beds are present. Upstream a fault trends about N. 30° E. with dolomite to the west. The dolomite is well exposed as massive beds in a bluff at the first bend upstream. *Eccyliomphalus*[63a] and *Gasconadia* are abundant, which suggests that the marble is in the Threadgill member of the Tanyard formation.

Megascopic description.—Sample G–22 has markings suggestive of filled burrows. The marble is of attractive appearance except for some dark brown limonite. The filled burrows are light yellowish brown with some variation in intensity of color. The groundmass of the rock is grayish buff, and there is a strong color contrast between it and the filled burrows. If sufficient stone of this type could be found, free of limonite, it would have many decorative uses.

Sample G–23 collected stratigraphically lower is an ivory-colored marble with a minimum of yellowish markings. The marble takes an excellent polish.

Microscopic description.—Sample G–22 is composed predominantly of dolomite and a small amount of calcite. The calcite is mostly very fine grained, and the dolomite rhombs and grains range up to about one-third of a millimeter in size. The dolomite and calcite contain innumerable small inclusions. A staining test reveals that the burrows are about equal proportions of calcite and dolomite and that the rest of the marble is dolomite.

[63a] *Eccyliomphalus* should read *Lytospira* throughout this paper. [Author, 1947.]

Sample G–23 is composed almost entirely of calcite, mostly in very fine-grained clouded areas surrounded by a network of somewhat coarser grained clear calcite. Some of the clouded areas appear to have a structure suggestive of fossil remnants.

Recommendations.—The beds are rather thin and consequently this marble is chiefly of value for pitched face stone.

LOCALITY G–24

Location and geology.—A deposit of Ellenburger calcite marble probably in the Gorman formation is located about 4 miles southeast of Fredericksburg and about one-half mile north of the Fredericksburg-Austin highway bridge across Pedernales River. The deposit is about 500 feet north of Pedernales River. A map of a small area including this outcrop is shown in figure 17.

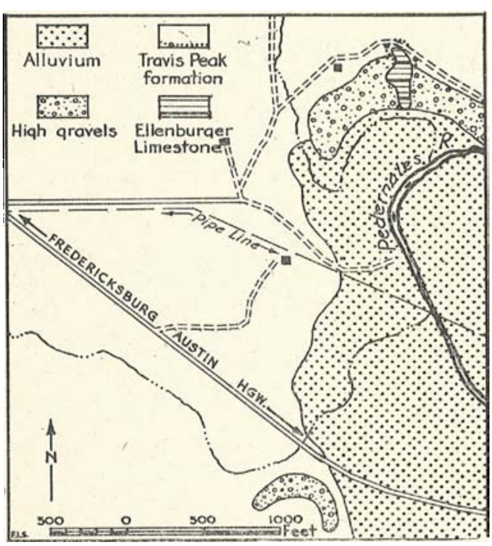

Fig. 17. Geologic map of an area 4 miles southeast of Fredericksburg, Gillespie County, Texas.

The marble is exposed for about 400 feet along a side drain of Pedernales River and at the widest point is little over 100 feet wide. The outcrop is rather insignificant in size but may be very extensive at a shallow depth beneath terrace gravels and Travis Peak sands which overlap it. It is sufficiently above river level so that a quarry could be established with little danger of floods. The upper end of the outcrop consists largely of boulders which may constitute a basal Cretaceous conglomerate.

Megascopic description.—Two samples of the marble were secured from different beds. One sample is light grayish cream with very faint purplish markings parallel to an undulatory structure, which suggests that this might be a stromatolite limestone. Calcite veins cut the structure transversely. The other sample has the same basic color but is sprinkled by small brown spots which are not of uniform distribution. The two marbles take an excellent polish.

Microscopic description.—The brown-spotted marble is composed predominantly of very fine-grained calcite and a small amount of dolomite. The dolomite is mostly present as imperfect rhombs which have been partly destroyed. The dolomite is clouded by numerous inclusions which are arranged in bands of varying density. The most prevalent type has a dense band about 1/30 of a millimeter thick a distance of about 1/30 of a millimeter from the outside edges of the rhombs, a few of which are clear in the center. The dense bands are yellowish by reflected light. Stylolites in the marble are tight, and a small amount of bright red material is located along them. The stromatolite-like marble was not thin sectioned. A staining test reveals that it is composed of calcite.

Recommendations.—The outcrop area is small and the overburden is probably rather thick. It is doubtful that this marble could be produced commercially.

Llano County

LOCALITY LL–4

Location and geology.—A deposit of Ellenburger calcite marble is located along Honey Creek about 11.5 miles southeast of Llano. It is exposed for a distance of about 1 mile along the creek and in the Riley Mountains on either side. The marble dips downstream and is about 600 feet thick, some of it in beds up to as much as 5 feet in thickness. Many beds are composed entirely of calcite, some beds contain chert, and a few were seen which contain pyrite. The presence of quartz grains suggests that the sample was obtained from the Gorman formation. Both Gorman and Honeycut rocks are exposed along Honey Creek, but the sandy basal portion of the Honeycut formation seldom contains limestone beds suitable for building stone.

Megascopic description.—A polished specimen from this locality is predominantly ivory-colored with a grayish-buff background. The ivory-colored areas appear to be either breccia fragments or possibly an edgewise type conglomerate. Some fossil fragments are present in the darker colored undisturbed portion of the marble. Narrow clear calcite veins trend approximately at right angles to indistinct stylolites. Some pyrite and limonite are present. The marble takes a brilliant mirror-like polish.

Microscopic description.—The marble is composed predominantly of very fine-grained cloudy calcite abundantly veined by coarse-grained clear calcite. A very small amount of angular quartz, mostly less than 1/20 of a millimeter in size, and a few scattered grains of dolomite are present.

Recommendations.—An enormous amount of marble is present in this area. Its color is attractive but not spectacular. The marble is of value as a building stone and for some interior uses.

LOCALITY LL–47

Location and geology.—A calcite marble deposit in the Threadgill member of the Tanyard formation is located on the eastern side of the Riley Mountains, about 15 miles by road southeast of Llano, is up a small creek about one-half mile from the foot of the Riley Mountains and from the nearest road. The road to Llano is graded but otherwise is little improved. The marble is light colored with delicate tracings of red. The lower part of the outcrop is massive with beds about 5 feet thick. The upper part of the outcrop is thinner bedded and contains two zones each about 5 feet thick of very thin-bedded argillaceous limestone unfit for use. A thickness of about 75 to 100 feet of good marble is present. The marble strikes about east-west and dips southward between 1° and 15°. No chert is present.

Megascopic description.—A polished sample of the marble is of a light ivory color with small areas of white, yellow, and faint green of random distribution. The white areas are coarsely crystalline dolomite. The sample has many incipient cracks apparently developed during the quarrying of the stone. The marble takes a brilliant mirror-like polish.

Microscopic description.—The marble is composed predominantly of calcite, most of which is very fine grained and somewhat clouded. In addition some areas of almost clear coarse-grained calcite have grains as much as 3 mm. in size. The clear calcite forms a broken network about the fine-grained calcite, and some fine inclusions are present. Dolomite, none of which was included in thin section, is recognized by staining.

Recommendations.—The marble is of good color and takes an excellent polish. The physical properties indicate that it is durable. A large amount of marble is exposed in this area. It is a very desirable building and ornamental stone.

San Saba County

LOCALITY S–1

Location and geology.—A calcite marble quarry in the Threadgill member of the Tanyard formation is located on the north bank of Buffalo Creek 3.1 miles by road east of the Cherokee-San Saba highway at a point 12.1 miles south of San Saba. The highway is hard surfaced and the last 3.1 miles of road to the quarry is very rough and unimproved. The marble is horizontally bedded and light colored. It is free of chert but has an occasional narrow stringer of dolomite in it. A quarry has been opened in the marble to a depth of approximately 50 feet. Water in the quarry stands 15 feet below the surface. The upper 5 feet of the marble is open along stylolites and joints. The next ledge is 6 feet thick and is a good massive stone. Beneath this is 2 feet of poor stone followed by about 2 feet of good stone to water level. The character of the stone beneath water level could not be ascertained.

Of the several quarries opened by the Vermont Marble Company, this one is the most promising. Some of the other quarry sites were visited but not sampled. They are described in the following paragraphs, and their location is shown in Plate 1.

On the H. Perry ranch, just east of the San Saba-Cherokee highway at a point about 10 miles south of San Saba, a small quarry (S–1a) has been made in a calcite marble of the Staendebach member of the Tanyard formation. The quarry is about 30 by 50 feet in size and about 10 feet deep to water level. The marble contains abundant chert. One ledge, probably from beneath the water, is fairly free of chert as revealed by chert-free blocks lying about the quarry. The stylolites are in straight lines and are rather open.

On the W. R. Payne ranch, 3.5 miles by road east of the Cherokee-San Saba road at a point about 5.5 miles south of San Saba, a small quarry (S–1b) has been opened in a cherty calcite marble in the uppermost beds of the Staendebach member of the Tanyard formation. The color of the stone is good but the chert destroys its value as a building stone.

The Murray quarry (S–1c) is located one-quarter of a mile west of the San Saba-Chappel road in the Gorman formation at a point about 4.5 miles southeast of San Saba. The quarry is about 200 by 225 feet in maximum dimensions and about 25 feet deep to water level. Much stone has been produced from this quarry, even though it is one of the poorest stones examined. The stylolites are open and numerous pyrite nodules are present which weather, causing unsightly streaks. Chert it absent.

Another quarry (S–1d) located to the west of the road about one-half mile nearer San Saba, also in the Gorman formation, was not visited.

Megascopic description.—The marble is predominantly grayish buff in tone with individual areas of ivory, buff, and light gray. Stylolites are abundant; some are dark colored, others are marked by light gray dolomite, and portions of some have a greenish-gray tint. Veins and cavity fillings of clear calcite and a few small unfilled cavities are present. A small number of fossils are exposed on the polished surface. The marble takes a brilliant polish which is only slightly affected by the dolomite present. It is well marked and of a pleasing color. Another bed from this deposit is composed of equal amounts of ivory-colored calcite and pink dolomite. A few clear narrow calcite veins cut the marble. The calcite takes an excellent polish and the dolomite a fair polish.

Microscopic description.—The marble in the Threadgill member is composed predominantly of calcite and a small amount of dolomite. The calcite is mostly very fine grained with veinlets and some diminutive network structure of coarse-grained calcite cutting it. The dolomite is in veins with crystals ranging up to 4 mm. or more in size, many of which have undulatory extinction. The dolomite appears to have originated after the calcite veins formed, as indicated by dolomite rhombs which extend entirely across these veins and into the fine-grained calcite for a substantial distance on both sides. Some of these rhombs include areas of calcite. No minerals other than the carbonates were identified. The dolomite and fine-grained calcite are clouded by innumerable inclusions; the vein calcite is without inclusions.

Recommendations.—The quarry located on Buffalo Creek contains some good marble. If the beds of good marble were quarried and the poor marble beds discarded, a creditable product could be produced. The rest of the quarries of this group cannot be recommended for building stone.

LOCALITY S–3

A calcite marble deposit in the Honeycut formation is located about 5 miles from San Saba along the road to Bend. The nearest point on a railroad is about 2 miles distant. The sample was collected from the road right-of-way. The marble is ivory-colored with a few small yellow flecks and some stylolites which are essentially gray. The marble takes a brilliant mirror-like polish. The marble was not thin sectioned; however, a staining test shows it to be composed entirely of calcite. The marble is not well exposed and core drilling would be necessary to determine the amount present.

LOCALITY S–8

Location and geology.—A deposit of calcite marble probably in the upper massive limestone member of the Gorman formation is located 0.7 miles west of the Gibbons ranch road at a point 3.0 miles southwest of Richland Springs. The road to Richland Springs is mostly graded but otherwise unimproved. The marble is exposed in caverns along joint planes, some of which extended to a depth of 50 feet. The bedding planes are far apart and the rock is massive. It is lighter colored than most Ellenburger marbles of San Saba County and appears to be a good stone. A small amount of chert is present.

Megascopic description.—The marble is of an ivory to buff color with small reddish-brown and white spots of random distribution. Stylolites in the marble are in part lined by dull red and grayish white. The marble takes a brilliant mirror-like polish.

Microscopic description.—The marble is composed predominantly of very fine-grained cloudy calcite and a small amount of network-like clear coarser grained calcite. Stylolites are rather abundant. Many of them are tight, but others have small openings along them, indicating some weakness. Some red and yellow cloudy materials are localized along the stylolites.

Recommendations.—The marble at this locality is of rather pleasing appearance and seems to be of good quality. A large amount of it is present. It should be of value as an interior building stone.

LOCALITY S–10

Location and geology.—A deposit of calcite marble probably in the Gorman formation is located about 8.5 miles by road from the nearest point on the railroad, which is at Algerita. About 6 miles of the road is graded but not otherwise improved and the rest of the road is a fair pasture road. The marble is well exposed at the head of Cedar Hollow which has cut a 50-foot gorge with vertical side walls and a width of about 75 feet. The marble is well bedded with many 18 to 24-inch thick beds. Many thin-bedded shaly layers are present. The solid thick beds are good stone, but considerable waste would result from thin-bedded layers. One bed contains gastropods 4 inches in diameter. Another thin bed contains small stromatolites 18 inches across and 4 inches thick. At the end of the gorge is a small flat covered by thin beds of crinoidal limestone which is probably the Chappel limestone. Typical black Marble Falls limestone outcrops a short distance to the east.

Megascopic description.—The marble is composed of innumerable small ivory-colored fragments somewhat lighter in color than the surrounding matrix. Some fossil fragments are visible on a polished surface. It has a uniformity in texture and composition which is very pleasing. The marble takes a brilliant mirror-like polish.

Microscopic description.—The marble is composed predominantly of calcite, much of which is very fine grained and cloudy. The fine-grained calcite is surrounded by a well developed network of clear coarse-grained calcite. No minerals other than calcite were recognized.

Recommendations.—The marble is rather thin bedded and is mostly of value for pitched face stone.

LOCALITY S–14

Location and geology.—A deposit of Ellenburger calcite marble is located about 28 miles south-southwest of Harkeyville, which is the nearest point on a railroad. The road for 25.5 miles of the distance is graded but otherwise unimproved. The last 2.5 miles to the deposit is over a very rough pasture road. Mr. Parkinson states: "This is one of the most desirable Ellenburger localities in San Saba County. A 30-foot bluff along the creek exposes massive beds up to 8 feet thick. There is no chert in the deposit."

Megascopic description.—The marble is mottled with strong contrast between ivory-colored calcite and brownish-gray colored dolomite areas. A small amount of yellow is located along some of the stylolites which are otherwise inconspicuous. Fossil fragments are rather abundant in the ivory-colored areas. The marble takes a brilliant mirror-like polish.

Microscopic description.—The marble is composed of calcite and dolomite. Calcite is the most abundant mineral and is predominantly very fine grained and cloudy. Some of the calcite is partly clear, coarsely crystalline, and in veins, and contains numerous fossil remnants. The dolomite is in rhombs and grains one-third of a millimeter in size mostly aggregated in irregular-shaped areas and seldom is present as individual rhombs surrounded by calcite. The dolomite is uniformly clouded by numerous very small inclusions. The marble contains a very small amount of angular quartz grains mostly less than 1/15 of a millimeter in size.

Recommendations.—The marble is of good quality and is probably quite extensive. It is, however, far from a railroad.

LOCALITY S-18

Location and geology.—A deposit of Ellenburger calcite marble is located about 9 miles by graded but otherwise unimproved road south of Richland Springs along the Brady Creek lower crossing road. To the east of the road is a dip slope covered by flat slabs of calcite marble. The surface rock is somewhat thin bedded, but in a joint plane cavern about 20 feet deep the beds appear to be more massive with depth. The color is the same as that of most of the San Saba County marbles examined. The marble is free of chert. Large surfaces are present free of joints, indicating that large blocks could be quarried. About a mile to the northeast much Ellenburger marble is present in beds about 18 inches thick. The marble outcrop is almost free of vegetation except along joints.

Megascopic description.—The marble is a rather featureless ivory to buff-colored stone which has some irregular cracks filled by white or yellow-stained material. The marble takes a brilliant mirror-like polish.

Microscopic description.—The marble is composed predominantly of very fine-grained calcite. A very small amount of coarser grained calcite is present mostly as very thin veinlets. No minerals other than calcite were recognized, but staining reveals a very small number of minute dolomite rhombs.

Recommendations.—The color of the marble is rather neutral. It takes an excellent polish and appears to be a durable stone. The deposit is rather large and is of value as a building stone.

LOCALITY S-19

Location and geology.—A calcite marble deposit in the Threadgill member of the Tanyard formation is located east-northeast of Cherokee, a distance of 5.3 miles by road which is mostly graded but not otherwise improved. The deposit is 1.5 miles north of the Cherokee-Chappel road a short distance west of Salt Branch of Cherokee Creek and 1400 feet a little west of north of the Mrs. J. C. Harris ranch house.[63b] A 30-foot bed of calcite marble is present with dolomite both above and below it. The bed strikes N. 45° W. and dips 60° to the northeast. The outcrop is on a gentle slope and is exposed as nearly flat low-lying surfaces, some of which are 6 to 8 feet wide and 30 to 40 feet long. The marble is almost free of joints and is massive without openings along the beds. The bed was traced 650 feet to the southeast. It continues across the fence to the northwest but was not traced in this direction. The steep dip indicates that the marble is near a fault. *Girvanella* limestone of the Wilberns formation is present a few hundred yards to the southwest. The marble is an exceptionally sound and beautiful stone.

Megascopic description.—The marble is light ivory with a very faint pinkish tint. Stylolites with dolomite along them are very abundant and are gray and grayish brown. The stylolite coloring and pattern produce a very attractive stone. Some fossil fragments are present in the ivory-colored portions. The marble takes a brilliant mirror-like polish which is only slightly affected by the dolomitic stylolite seams.

Microscopic description.—The marble is composed predominantly of calcite rang-

[63b]Cloud, P. E., Jr., Barnes, V. E., and Bridge, Josiah, Stratigraphy of the Ellenburger group in central Texas—a progress report: Univ. Texas Pub. 4301, Pl. IV (geol. map of a part of the Cherokee area), 1943 [June, 1945].

ing from fine-grained to grains one-fifth of a millimeter in size with some veinlets of coarse-grained calcite. A very small number of cloudy dolomite rhombs are present. No other minerals were recognized and the calcite is almost free of inclusions. A few fossil remnants are present. Staining reveals that the stylolites have a concentration of dolomite along them.

Recommendations.—The marble is of exceptionally good quality and is a beautiful stone. The attitude of the bed would make quarrying difficult.

LOCALITY S–23

An Ellenburger calcite marble deposit is located 2 miles southeast of the Cherokee-Chappel road at a point 5.5 miles east of Cherokee. The marble is well exposed along the road especially to the south where solution along joint planes has produced caverns to a depth of 20 feet. So far as can be seen by looking down these joint planes, the stone is solid for the entire distance. At the surface large areas of sound stone are exposed. The marble is light colored, dense, and free of chert.

LOCALITY S–24

A calcite marble quarry (Green quarry) is located 5.5 miles southeast of San Saba by road and about 1.5 miles north-northeast of the Murray quarry. The quarry is in the top of the Gorman formation. The upper 5 feet of stone is thin bedded and cherty. Beneath this, two beds 4 to 5 feet thick are present which are free from chert.

LOCALITY S–25

About one-half mile northeast of the Green quarry some thin-bedded stone has been quarried to build the attractive Methodist Church in San Saba. The stone is finished pitched face. The beds of stone are rather uniform in thickness, are sound, and are of a pleasing light color.

DOLOMITE MARBLES

Description by Localities

Blanco County

LOCALITY BL–2

Location and geology.—A quarry in the Pedernales dolomite member of the Wilberns formation is located 7.7 miles west of Johnson City and 21.5 miles east of Fredericksburg. The outcrop is along Rocky Creek about 100 yards north of the paved Johnson City-Fredericksburg highway. The dolomite has some porosity, and along some bedding planes there are numerous filled burrows in a limy-shaly material. The dolomite is very good for crushed rock and, in places, may be sufficiently massive for building stone. On the quarry bottom is an inch-thick layer of limestone completely covered by trilobites and other fossils which stand out in relief. These fossils were sent to Dr. Josiah Bridge, of the U. S. Geological Survey, who kindly furnished the following information:

> In this collection I can recognize the following forms, among others:
>
> Trilobites:
>
> Stenopilus—2 species
> Eurekia sp.
> Free cheeks and other fragmentary material of a form allied to Saukia or Briscoia
>
> Gastropods:
>
> Sinuopea cf. sweeti
> "Ophileta" primordialis

Megascopic description.—The marble is mottled with buff areas and a few light-colored areas on a background of gray. Some porosity is present and some of the pores have been filled with colorless calcite. The marble takes a good uniform polish which, however, is not brilliant.

Microscopic description.—The marble is composed almost entirely of dolomite. A very small amount of impurities is present consisting of a few very small green grains resembling glauconite and a few areas of small radial spherulites having a low birefringence. Each dolomite grain is sprinkled by very fine inclusions. The dolomite is mostly in rhombs which average about a quarter of a millimeter in size. A thin section, when viewed by low magnification, reveals some rounded to angular areas in which the dolomite is more translucent because of less included material. Near the northern end of the quarry the dolomite is brecciated. A thin section of the breccia reveals dolomite grains up to 3 mm. in size, many of which have undulatory extinction and are surrounded by a mylonite composed of dolomite.

Recommendations.—The dolomite is of a rather neutral color and takes a good polish. A large amount of dolomite is present in the deposit. The physical properties indicate that it is a durable stone. Some of the dolomite in sufficiently thick beds might be utilized as a building stone, but mostly this deposit is of value for crushed stone.

LOCALITY BL-16

Location and geology.—A deposit of dolomite marble probably in the Pedernales dolomite member of the Wilberns formation is located about 7 miles from Round Mountain along the Round Mountain-Llano road which is graded but otherwise unimproved. The deposit is 18 miles by road via Round Mountain from the nearest railroad, which is at Marble Falls. The highway from Round Mountain to Marble Falls, a distance of 11 miles, is hard surfaced. The dolomite is rather thin bedded and is in part marked by purple bands. The dolomite varies widely in color and cannot be expected to be colored in this manner below the depth to which weathering reaches. A very large area of dolomite outcrops in the area and might furnish a fair amount of marble colored in various patterns.

Megascopic description.—The dolomite has well developed, closely spaced bedding laminae alternating between pinkish-cream and light purple in color. Some of the bedding planes are slightly wavy, suggesting current action during deposition. Color bands and patterns of maroon color cross the bedding and extend along it, producing a very colorful rock. The dolomite takes a good uniform but not brilliant polish.

Microscopic description.—The marble was not thin sectioned, but a staining test reveals that it is composed entirely of dolomite.

Recommendations.—The dolomite is attractively colored at the surface, but below ground water level it probably will be gray. A large amount of surface stone is available.

LOCALITY BL-17

Location and geology.—A dolomite marble sample probably in the Pedernales dolomite member of the Wilberns formation was collected about 0.4 mile along the road west of Bl-16 and is a continuation of the same dolomite outcrop. The dolomite is similar to that described under Bl-16. A sample obtained from this locality is the most unusual and most beautiful marble collected in central Texas. The rock is light gray with purple markings along the bedding planes. The purple markings also extend outward from the bedding planes as tree-like dendrites forming a pattern suggestive of a landscape in a Japanese painting. The area between Bl-16 and Bl-17 is a continuous outcrop of dolomite in which much extraordinarily colored stone might be present.

Megascopic description.—The dolomite in this area varies widely in color and texture. Much of the stone has purple markings as narrow seams and irregular splotches on a background of various shades of buff. The ultimate in beauty is the picture stone which has purple dendritic markings arranged in such a manner on a background of various shades of buff that it looks entirely like a Japanese landscape painting. In some dolomite of the area the markings are maroon with a background of mottled pink and very faint green. Dolomite of this type is brecciated and somewhat porous. The dolomite takes a good uniform polish, which, however, is not brilliant.

Microscopic description.—The dolomite is composed essentially of the mineral dolomite. A small amount of quartz is present as angular grains 1/15 of a millimeter or less in size, and a few grains of a green mineral of about the same size may be glauconite. The dolomite is mostly in rhombs and grains one-fourth of a millimeter in size. A few areas which are slightly darker in color are also composed of slightly larger dolomite grains. All of the dolomite crystals contain minute inclusions. A staining test revealed a few isolated grains of calcite in one specimen.

Recommendations.—Much attractively colored dolomite outcrops in this area. It is a novelty stone which could be used as an ornamental stone and is also highly suited for crushed stone.

LOCALITY BL-18

Location and geology.—A deposit of dolomite marble in the basal portion of the Pedernales dolomite member of the Wilberns formation is located just south of the Round Mountain-Llano road at a point 0.6 miles west of Round Mountain. The distance to the nearest railroad, which is at Marble Falls, is 12 miles. The dolomite is exposed in Cypress Creek for a distance of about 700 feet as a large smooth surface. It is gray and dips gently downstream to the southeast. The dolomite is more massive than most of the dolomites of the area. The bed sampled is the basal bed of the Pedernales dolomite member of the Wilberns. The same bed outcrops to the southeast across a ridge of Cretaceous sediments and can be followed across the highway south of Round Mountain.

Megascopic description.—The dolomite is somewhat drab in color and is composed of an irregular pattern of shades of grayish purple and gray tinged with green. A small amount of porosity is in part filled with clear calcite. Stylolites are rather inconspicuous and appear to be tight. The dolomite takes a fairly uniform but not brilliant polish.

Microscopic description.—The dolomite is composed essentially of the mineral dolomite. A very small amount of angular quartz and feldspar grains 1/15 of a millimeter in size is present. The dolomite grains and rhombs averaging about one-half of a millimeter in size are almost free of inclusions. Some flecks of red are concentrated along grain boundaries. A very few small green grains may be glauconite.

Recommendations.—The dolomite is of rather a neutral color and takes a fair polish. The outcrop is mostly along one bed, and core drilling would be necessary to determine the amount of desirable stone present. It is of value for a building stone and for crushed rock.

LOCALITY BL-22

Location and geology.—A dolomite marble deposit in the lower dolomitic facies of the Gorman formation is located 3.3 miles east along the Cypress Mill road from its intersection with the Johnson City-Marble Falls highway at a point 19 miles south of Marble Falls. Weathered surfaces of the dolomite are white. The dolomite is microgranular, contains numerous narrow veins, and in part has an appearance much like that of "lithographic limestone."

Megascopic description.—The dolomite is light brownish gray and is speckled by irregular-shaped areas of brown. A few tight knife-edge joints are present in which the brown coloration is a little more intense, with the rock an eighth of an inch on either side free of brown specks. The limonite causing the brown coloration has apparently migrated to the joints. The dolomite takes a good uniform polish which, however, is not brilliant. The dolomite was not thin sectioned, but a staining test reveals that it is composed of the mineral dolomite.

Recommendations.—The deposit may be usable in part as lithographic limestone. Otherwise it is too thin bedded for any use except as pitched face stone or crushed rock.

Burnet County

LOCALITY BU-4

Location and geology.—A dolomite marble deposit in the Honeycut formation is located 2 miles by road south of Marble Falls along Flatrock Creek just south of the Marble Falls-Spicewood road. The dolomite is thin bedded, the maximum thickness being about 18 inches. Most of the beds average 10 inches in thickness. One bed is a dense, white, dull lithographic-like stone and varies in thickness between about 12 and 18 inches. Some chert is present. The dolomite dips gently downstream to the north.

Megascopic description.—The dolomite is mottled with light gray and light buff areas on a background of medium gray. A slight stylolitic development is present but is inconspicuous. The calcite areas polish with a mirror-like surface and the dolomite areas take a good uniform but not brilliant polish.

Microscopic description.—The marble is composed of dolomite grains one-fifth of a millimeter in size in extremely fine-grained calcite. Dolomite is probably the most abundant of the two minerals and is very irregularly distributed. Some areas are almost pure dolomite while others are almost pure calcite. The dolomite is mostly in the shape of perfect rhombs especially where surrounded by calcite. A few fossil fragments are present.

Recommendations.—The marble is a mixture of dolomite and calcite which upon polishing produces a surface in part mirror-like and in part less brilliant. The beds in no place are over 18 inches in thickness. The marble is of good quality and is of value for pitched face building stone and for crushed rock.

LOCALITY BU–20

Location and geology.—A deposit of dolomite marble is located along Hamilton Creek and near the railroad at the south city limits of Burnet. The dolomite has been used for terrazzo chips and is very good for this purpose. It varies in color from pink to red with the latter containing mottles and dendrites of manganese oxide. The dolomite outcrop is about 75 by 350 feet in size and test pits encountered it beyond the outcrop limits. Other small outcrops are located upstream, and one outcrop located about one-half mile downstream is a calcite marble similar to Bu–11, described on page 137.

Basal Cretaceous sandstone, in part iron oxide cemented, overlies the marble on both sides of the creek and in places conceals it from view in the creek. The marble has been subjected to two periods of exposure at the surface, one before the Cretaceous sandstones were laid down and the other during the present cycle of erosion. This protracted exposure to weathering is probably responsible for the deep red color of much of the stone.

Megascopic description.—The dolomite is predominantly pink with breccia-like areas of ivory color. Many clear calcite veins ramify across its surface. The rock contains some rather unsightly color areas of yellow-brown to black and a few chalky white areas in part brownish and pinkish in color. The dolomite appears to be a breccia produced during the pre-Cretaceous period of weathering followed by recementation at which time it became colored. The breccia-like ivory-colored fragments take a brilliant mirror-like polish and the matrix takes a very dull polish.

Microscopic description.—The dolomite is composed predominantly of the mineral dolomite in grains ranging widely in size to an upper limit of about one-third of a millimeter. About 10 to 20 per cent of the rock is calcite either as extremely fine-grained areas or as coarse-grained veinlet-like elongated areas. The marble contains a few mostly well-rounded quartz grains up to one-third of a millimeter in size.

Recommendations.—The stone is low lying and much of it is covered by overburden; consequently, quarrying would be expensive. This might be offset to some extent by the nearness of the deposit to the railroad. The inability to polish the red portions would preclude the use of this stone for ornamental purposes.

LOCALITY BU–34

Location and geology.—A quarry in the lower dolomitic facies of the Gorman formation is located 0.4 mile east of the Burnet-Lampasas highway at a point 13.4 miles north of Burnet and is about 1 mile west of a railroad. The dolomite has been quarried for road material. It is pink with red lines through it and well exposed downstream from the quarry in fairly massive beds which might be suitable for quarrying. A 2-foot zone of well-rounded, frosted, well-cemented white sandstone is exposed on the eastern face of the quarry. The base of the sand layer contains numerous dolomite fragments or pebbles having the appearance of an edgewise conglomerate. The central part of the bed is massive sandstone, followed by dolomite intercalated with sandstone. The sandstone is composed of frosted grains.

Megascopic description.—The dolomite is in part highly colored with red seams from which dendrites of deep red color extend outward. In addition, color bands outline areas between the red seams. These color bands range from light yellow to a mild purple with areas between that are light grayish white. The dolomite takes a good uniform but not a brilliant polish.

Microscopic description.—The dolomite is composed almost entirely of the mineral dolomite, the grains of which average about 1/30 of a millimeter in size. No mineral other than dolomite was identified. Some very small inclusions are contained in the dolomite, and by reflected light some irregularly distributed red cloudy material is visible along grain boundaries.

Recommendations.—The dolomite is of rather a nice color and takes a fair polish. It is of good quality. Some beds may be sufficiently thick to quarry for building stone. It is a desirable building stone and is excellent for crushed rock.

LOCALITY BU-35 (VICTORIA GRAVEL COMPANY QUARRY)

Location and geology.—A quarry in dolomite of the lower part of the Staendebach member of the Tanyard formation is located east of the railroad north of Sudduth. A railroad spur has been built and a crushing plant installed. At the time the plant and quarry were visited, October 29, 1938, the quarry had been in operation for one year. During that time dolomite had been removed from an area about 650 by 800 feet in size and to a depth of 30 feet at the uphill side of the quarry. The capacity of the crushing plant is about 50 carloads a day. In a quarry opened in the upper part of the Threadgill member of the Tanyard formation during 1942 west of the railroad, the dolomite is used for the production of magnesium. Two plants used this dolomite, namely, International Minerals and Chemical Corporation at Austin, Texas, and Mathiesen Alkali Company at Lake Charles, Louisiana.

Megascopic description.—The dolomite is predominantly of a mottled gray color suffused with light purple. The dolomite crystals are sufficiently large and variable in color so that a fine dappled appearance is produced throughout. The dolomite takes a good polish.

Microscopic description.—Dolomite in rhombs mostly less than one-fourth of a millimeter in size is the predominant mineral. Some red iron oxide is situated along grain boundaries. The dolomite rhombs are clouded, with a tendency for the borders to be less cloudy than the centers. A bleached, narrow, vein-like streak crosses the bedding. Dolomite rhombs situated entirely across this streak are clear for the width of the streak and cloudy at both ends. A stylolite seam is filled by a cloudy material and some remnants of dolomite crystals.

Recommendations.—The dolomite is being used extensively for crushed aggregate and in addition has been used for the production of magnesium. An enormous amount of dolomite is available in this area. Some of it might be usable as a building stone.

LOCALITY BU-36

Location and geology.—A dolomite quarry probably in the Threadgill member of the Tanyard formation is located along the railroad near Sudduth and just west of the Burnet-Marble Falls hard-surfaced highway. The dolomite was used for crushed stone for highway surfacing, terrazzo chips, and concrete aggregate. The rock is somewhat cavernous and porous. A fault to the west of the quarry drops the dolomite against Cap Mountain limestone. The dolomite is somewhat brecciated in places because of this faulting.

Megascopic description.—A polished piece of the dolomite reveals zones of breccia, the fragments of which are mostly light in color surrounded by a brownish-red coloration. The non-brecciated stone is mottled pinkish gray to brownish gray in color. Several small cavities are present and the dolomite takes a fairly uniform but not brilliant polish.

Microscopic description.—The dolomite is composed essentially of the mineral dolomite. A very small number of calcite grains are present. The dolomite grains are large, many measuring 2 mm. in size. Undulatory extinction is common and in places the dolomite appears to have been crushed. Several dolomite crystals are clouded by innumerable inclusions at the center with optically continuous clear dolomite at the borders. The variation in cloudiness gives the thin section a mottled appearance. A small amount of red cloudy material is concentrated at grain boundaries.

Recommendations.—The dolomite is of value for crushed stone. It is strong and durable but apparently is not in sufficiently massive beds to be used as a building stone.

LOCALITY BU–39

A dolomite marble deposit is located west of the Burnet-Marble Falls highway about 1 mile south of Burnet. The dolomite is not well exposed and drilling would be necessary to determine its extent and value. The dolomite may be Cambrian in age. The dolomite is mostly a rather deep shade of pink enclosing areas having a rather deep brownish-gray color. Incipient cracks in the stone are of a deep purplish-red color and dendrites of the same color extend outward from the cracks. A small amount of porosity is present. The dolomite takes a uniform but rather dull polish. It has been used for terrazzo chips and is probably mostly of value for this use and for other crushed rock products.

LOCALITY BU–44

A dolomite marble deposit in the dolomite facies of the Gorman formation is located just east of the Marble Falls-Burnet highway at a point 3.1 miles south of the railroad at Sudduth. The dolomite is red, brecciated, and is along a fault which has dropped it against Hickory sandstone to the west. It is used for terrazzo chips and is very good for this purpose. The dolomite contains small cavities, some chert, and is in part white veined. It is beautiful but rather limited in extent. The dolomite is dark red and is veined by white to brownish-white, in part anastomosing, veins. It is a very attractive dense stone which takes a very good polish. The dolomite, however, is in part cavernous and in part contains chert and would have to be selected with care for building stone use. A small number of saw blocks might be obtained from the deposit.

Gillespie County

LOCALITY G–17

A deposit of dolomite marble probably in the Staendebach member of the Tanyard formation is located about 1 mile north of the hard-surfaced Johnson City-Fredericksburg highway at a point about 7 miles east of Fredericksburg. The dolomite is exposed in Pedernales River with the main outcrop to the north of the river. It is cherty, much jointed, of a pleasing pink color, and if solid beds could be found might be of value. The dolomite is grayish-ivory with purple markings. The markings resembling somewhat faint color bandings are most intense along incipient joints and between joints. These bands are not uniformly colored and are composed of minute purple specks varying in density of distribution. The dolomite takes a good uniform polish. The dolomite was not thin sectioned; however, staining tests reveal that it is composed entirely of the mineral dolomite. The deposit is situated rather low along the bank of Pedernales River. Some rather massive ledges are present, but in general they are chert bearing and not suited for building stone. This deposit is chiefly of value for crushed stone.

LOCALITY G–18

Location and geology.—A deposit of Cambrian dolomite marble is located 9.5 miles east of Fredericksburg and along Pedernales River at Blumenthal. A map of a small area in this vicinity is shown in figure 14. The dolomite is the Pedernales dolomite member of the Wilberns formation. It directly overlies somewhat dolomitic Wilberns limestone. The marble is a coarsely crystalline pink dolomite in part brecciated. Another outcrop of Pedernales dolomite containing some chert and silicified fossils is located one-half mile to the south.

Megascopic description.—A brecciated piece of the dolomite was polished. The breccia fragments are rather dark colored and essentially brown. The fritted material between the fragments is deep reddish brown in color. The dolomite is quite porous and takes a rather poor polish.

Microscopic description.—The dolomite is composed essentially of dolomite in grains and rhombs ranging up to 2 mm. in size. A very small amount of angular quartz ranges up to 1/15 of a millimeter in size. The dolomite contains abundant very small inclusions. Considerable yellowish and reddish cloudy material is situated along grain boundaries.

Recommendations.—The dolomite is low lying along Pedernales River and is not well situated for quarrying. This deposit is chiefly of value for crushed rock.

San Saba County

LOCALITY S–6

A deposit of Ellenburger dolomite marble is located about 20 miles south-southwest of Richland Springs and about one-quarter of a mile south of Brady Creek. The road to the deposit was impassable in 1938. Mr. Parkinson reports that ample stone of good quality is present at this place. It is free of chert, and he recommends that the deposit be core drilled. The dolomite is a mixture of dull pink and grayish ivory-colored areas. Clear calcite veins cross the rock and in part are bordered by narrow yellow bands. The dolomite takes a fairly brilliant, uniform polish. The dolomite was not thin sectioned; however, a staining test shows it to be composed entirely of the mineral dolomite.

Recommendations.—The dolomite is strong, durable, of good color, and takes a good polish. It is a desirable building stone and is of value for crushed stone but is now rather inaccessible.

LOCALITY S–11

A deposit of dolomite marble probably in the Gorman formation is located about 4 miles by road west of the San Saba-Pontotoc road at a point about 14 miles south of Harkeyville, which is the nearest point on a railroad to the deposit. The road is graded but not otherwise improved. A large area of dolomite is exposed along the divide between the headwaters of Wallace Creek and San Saba River. The outcrop is characterized by lack of vegetation. A polished piece of the dolomite has a muddy white color. The muddy, very faintly banded appearance is caused by minute limonitic brown specks and a trace of pink coloration. The dolomite takes very little polish. Microscopically the dolomite is composed predominantly of grains and rhombs of the mineral dolomite 1/10 of a millimeter in size. The dolomite contains minute inclusions, and some cloudy yellowish to reddish material is situated along grain boundaries. No beds were seen that would justify the establishment of a building stone quarry, but careful prospecting might reveal such beds. It is an excellent dolomite for crushed stone.

LOCALITY S–20

Location and geology.—A deposit of Ellenburger dolomite marble is located 20 miles by road southeast of San Saba. It is about 9 miles east of Cherokee and is east of the Cherokee-Chappel road. The road to San Saba is graded but otherwise unimproved. Mr. Parkinson reports that a bluff of dolomite is located along Davis Hollow which is a tributary of Cherokee Creek. The sample was obtained from this area.

In the same general area calcite marble is exposed for a distance of 1.3 miles along the Boyett ranch road starting at a point 0.2 mile from the Cherokee-San Saba road. The beds exposed along the road are mostly 12 to 18 inches thick; some that are thinner are of little value. The marble is white with some beds containing faint reddish markings. Some chert was seen, but in general much of the marble is chert free.

Megascopic description.—In color the dolomite is a combination of pinks and whites. The white has a pinkish cast, and the pinks vary from light to coral-pink with some pinks that are smoky. Stylolites are present and are mostly outlined by a coral-pink color. The dolomite takes a uniform but not brilliant polish.

Microscopic description.—The marble is composed predominantly of rhombs and grains of clouded dolomite one-third of a millimeter in size. The inclusions producing the clouding are more numerous in the centers of the grains. Small areas of optically continuous calcite interstitial to the dolomite probably is secondary, having filled small cavities in the dolomite. Some red cloudy material is situated along the dolomite grain boundaries. Staining reveals that about half of the polished sample is dolomite distinct from the other half, which is dolomite with fine calcite grains scattered throughout.

Recommendations.—The dolomite is of rather pleasing color and appears to form a large deposit. It might be of some value as a building stone.

Mississippian Crinoidal Marble

Description by Localities

Mason County

LOCALITY M-22

Location and geology.—A deposit of crinoidal limesand in the Barnett formation rests on the Ellenburger about 7.5 miles southwest of Mason and up Honey Creek about one-fourth of a mile west of the Honey Creek road. It is well exposed on the north side of the creek. The nearest railroad to this deposit is at Brady, a distance of about 37 miles. The marble strikes about N. 10° E. and dips about 15° to the east. The bottom 10 feet of the marble is massive without a bedding plane joint and the upper 10 feet is rather thin bedded. At this point the total thickness of good marble is about 20 feet. One set of joints trends east-west and dips 83° to the north. One block near the eastern side of the outcrop measures 30 feet between joints. The marble was traced for several hundred yards westward along the side of a steep hill.

The contact of the limesand and the Ellenburger is well exposed in the creek bottom. The Ellenburger to the west is mostly chert free and is an attractive stone, ranging in color through cream and darker shades. The Ellenburger is somewhat more jointed than the limesand of the Barnett, but some large blocks could be produced. Stromatolites cover an area about 40 by 75 feet in size in the creek bed. Individual stromatolites are about 5 to 6 feet across, and masses and layers of chert are associated with them. Above the stromatolites, thin-bedded limestone has assumed the shape of the rounded stromatolites, with the irregularity of bedding dying out upward within 5 feet.

Megascopic description.—The crinoidal marble is very light gray with a very faint tint of salmon. It is distinctly granular in appearance and is chiefly a mass of crinoid stems and other fossils, many of which are broken. A few small pebbles of limestone are incorporated with the fossil fragments. The marble takes an excellent polish.

Microscopic description.—The marble is composed entirely of calcite mostly as fossil fragments. Crinoid stems compose practically the entire rock and each stem section is an individual calcite crystal. Many of these stems have a grating or screen-like structure.

Recommendations.—A large amount of very attractive crinoidal marble is contained in the deposit which is of value as an interior marble.

Lower Pennsylvanian Marbles

Description by Localities

Blanco County

LOCALITY BL-19

A small deposit of crinoidal limestone in the base of the Marble Falls formation is located about 0.2 mile south of the Cypress Mill post office and along the road to Pedernales Falls. The deposit is about 19 miles from Marble Falls by way of Round Mountain. The crinoidal marble rims a small inlier of the Ellenburger formation outcropping in the bottom of a small creek. It is in a bed ranging from about 1 to 4 feet in thickness, and only a small amount of usable stone outcrops. The marble is dark gray to black and contains numerous white crinoid stems. Other outcrops of the limestone are exposed in Honeycut Bend, 5 miles east of Johnson City.

The marble is composed of numerous large nearly white crinoid stems in a brownish-gray matrix. The contrast between the crinoid stems and the matrix is marked, making a very unusual and attractive stone. The marble takes a brilliant mirror-like polish. The crinoidal marble is mostly of value as an ornamental or novelty stone.

Burnet County

LOCALITY BU-14

Marble Falls limestone extends from the Colorado River bridge at Marble Falls south for about three-fourths of a mile. This Marble Falls limestone is black, thin bedded, and rather highly jointed. The limestone is black with a grayish cast which produces a barely perceptible mottled appearance. It takes a somewhat dull polish. The limestone is composed predominantly of calcite, and a few sponge spicules composed of silica are present. The thin sections are crowded by fossil fragments including some crinoid stems which are composed of individual calcite crystals. The calcite is otherwise mostly fine grained. The limestone has been used for terrazzo chips and is chiefly of value for this purpose.

LOCALITY BU–19

A spotted black Marble Falls limestone outcrop is exposed in a road cut along the south bluff of Colorado River about 1 mile southwest of Marble Falls. The outcrop is located at the highest point reached by the road along the side of the bluff. The limestone has a background of dark gray somewhat speckled by very small black and brown specks, on which widely separated inch-size dark-colored areas are distributed. The limestone takes a dull polish and has a rather somber appearance. It is composed predominantly of calcite, fossil fragments, crinoid stems, microfossils, and considerable silica as sponge spicules. The limestone appears to be limited in amount, is of rather a somber color, and probably is of little value as a building stone.

LOCALITY BU–45

A deposit of black Marble Falls limestone is located within the north city limits of Marble Falls. The limestone is quarried for terrazzo chips. About 8 feet of limestone is exposed in the quarries, and it is exposed for a considerable distance along a small creek which passes near the quarries. The limestone dips about 5° to the southwest. Joints are closely spaced and one prominent set strikes N. 68° W. The limestone is of value for terrazzo chips but is too highly jointed to be of value as a building stone.

San Saba County

LOCALITY S–5

A Marble Falls limestone deposit is located near the San Saba-Bend road on the north side of Rough Creek crossing. The deposit is 12.5 miles from San Saba by road, 8.6 miles of which is graded but not otherwise improved. The limestone is in beds 6 inches to 2 feet in thickness and is well exposed in the north bluff of Rough Creek. A few hundred feet to the west is a large fault which trends about N. 30° E. and drops beds of Strawn age against the Marble Falls limestone. The fault is well exposed to the south on the G. H. Brister ranch. Sandstone flagging is present in the Strawn several hundred yards west of the fault.

The limestone is brown and is slightly mottled by grayish-brown areas. A few fossil fragments are present. The limestone takes a dull to fair polish and can be considered commercially as a marble. A rather large amount of stone in a situation favorable for quarrying is located along Rough Creek. It might be of value as a building stone.

LOCALITY S–7

Location and geology.—A deposit of crinoidal limestone from near the base of the Marble Falls limestone is located about 4.5 miles southwest of Richland Springs down Dry Creek about one-quarter of a mile from the old Gibbons ranch house. The road to Richland Springs is graded but not otherwise improved. The marble in the best exposure is composed of three beds. The upper bed 12 to 18 inches thick and the lower one 6 inches thick are of sound, gray-colored marble. The middle bed, 10 inches thick, is stained a rusty color. The beds strike approximately N. 45° E. and dip about 7° to the southeast. The marble is of striking appearance with large white crinoid stem segments in a gray limy matrix.

Megascopic description.—The marble is composed of light brown crinoid stems in a groundmass varying between brown and gray. It takes a good polish.

Microscopic description.—The marble is composed predominantly of calcite. The matrix is fine-grained calcite with some fossil fragments. The crinoid stems are composed of individual calcite crystals.

Recommendations.—The stone is not abundant and is of value chiefly as a novelty stone.

LOCALITY S-9

Location and geology.—A deposit of siliceous Marble Falls limestone is located about 11.5 miles by road south of Richland Springs. The road is graded but otherwise unimproved. Siliceous limestone is well exposed down a draw to the east of the road. It is well bedded in beds 4 to 18 inches thick. At the surface it is weathered, leaving a white, porous, siliceous rock which is in places purple banded. Only a small amount of banding is present, and it is likely that the siliceous light-colored rock is also limited. A few beds are present which are not entirely leached of lime. The original rock is ugly grayish black. Much leached rock is present in outcrops of the Marble Falls, but it is widely scattered and is nowhere very abundant. Between the outcrop and the road is a fault along which the Marble Falls is strongly upturned and downdropped against the Ellenburger formation. A house about 1 mile west of the outcrop has recently been faced with siliceous limestone.

Megascopic description.—The limestone varies in color, depending upon the amount of weathering. The unweathered stone is a dark gray somewhat mottled stone and is separated from the weathered yellow stone by a mottled purple band. The stone takes a fair polish and can be classified commercially as a marble.

Microscopic description.—A thin section of the unweathered stone was tested by staining for calcite. It stains as if it were entirely calcite, but weathered samples show that it contains a high percentage of very fine-grained silica. The stylolites have a concentration of isotropic to cryptocrystalline, brown, siliceous material along them. Sponge spicules are absent in thin section.

Recommendations.—The siliceous rock has been used locally to face houses, and its chief value is for this purpose.

LOCALITY S-16

Location and geology.—A deposit of leached siliceous Marble Falls limestone is situated about 1 mile south of Richland Springs. The silica rock is highly porous and is of very light weight. It has been quarried along the bank of a small creek for a distance of about 100 yards. The bed quarried is about 2 feet thick, and in places small unweathered remnants of the original grayish-black Marble Falls limestone are present near the center of the bed. A chimney built of this stone in 1883 is entirely unaffected by the weather, and the stone in the fireplace is unaffected by heat.

Megascopic description.—The silica rock is light gray and is somewhat harsh to the touch. It is an extremely porous stone with very fine pores and is light in weight.

Microscopic description.—The limestone, before it is weathered, is composed of finely crystalline material which contains abundant calcite. After it is weathered, it is composed of calcite crystals in a base of isotropic to cryptocrystalline material having a brownish cast. A powdered sample was boiled in hydrochloric acid. The residue is a cryptocrystalline or finely crystalline material having a refractive index near 1.547. This material is quartz. Another siliceous residue from equivalent beds was collected 4 miles southwest of Lampasas. This residue is composed of sponge spicules having a refractive index distinctly less than 1.547 and slightly greater than 1.533, which places it in the range covered by chalcedony. The thin section of the unweathered sample of S-16 contains a limited number of sponge spicules, and the thin section of the weathered sample is practically free of them. The significance of the variations in optical properties and physical constitution of these siliceous residues is not clear.

Recommendations.—The rock is heat resisting and should find many industrial applications. It is a surface rock formed by the weathering of the siliceous Marble Falls limestone. Only a small amount of the rock is present in any one area but the aggregate tonnage that can be obtained throughout the Marble Falls limestone outcrop area should be large.

LOCALITY S-17

Location and geology.—A deposit of Marble Falls limestone visited by Mr.

Parkinson is described by him as being "located about 11½ miles east of south from Richland Springs on the Harkeyville-Gibbons road and about ⅓ mile east from a reservoir in the corner of Gibbons' pasture. The marble is not well exposed and the quantity present could not be determined."

Megascopic description.—The limestone is composed of light chocolate-brown, irregularly shaped areas abundantly distributed in a very dark slightly brownish-gray background which contains a few crinoid stems and other fossils of light color. Transparent to white calcite veins are present but are not numerous. The limestone takes a good polish and is classified commercially as a marble.

Microscopic description.—The limestone in thin section is composed of light-colored areas in a dark-colored groundmass. Both areas are very abundantly fossiliferous. The fossils are abruptly truncated at the edges of the light-colored areas which must, therefore, be older than the matrix in which they are included. The type of fossil material is very similar in the two areas; consequently, it is assumed that this is an intraformational conglomerate or breccia produced by storms tearing up beds already somewhat lithified and mixing them with unconsolidated sediments of practically the same age.

Recommendations.—The limestone may be limited in amount; otherwise it is rather an attractive stone.

Mesozoic Building Stones (Cretaceous Period)

The portion of the Cretaceous containing building stone deposits has been reviewed on pages 15–16, and the building stones of most value in the Cretaceous are the limestones described on pages 167–170. Some beds of the Edwards limestone contain stone which is hard, compact, and takes an excellent polish. These stones are classified commercially as marbles. The portion of the basal Cretaceous conglomerate composed of limestone pebbles taking a high polish is also classified as a marble.

Basal Cretaceous Conglomerates

Many conglomerate deposits of building stone quality are situated at the base of the Cretaceous about the Central Mineral region. These conglomerates vary widely in composition, size of pebbles, and thickness. The Cretaceous seas encroached upon a distinctly uneven surface. Prominences such as Bear Mountain (pre-Cambrian granite), north of Fredericksburg (fig. 5), and the wide variation in elevation of the basal Cretaceous contact shown in figure 13 attest to the unevenness of this surface. On uneven surfaces basal conglomerates tend to seek topographically low areas, and where these areas are narrow valleys the conglomerate may be both thick and composed of large boulders. At Lange's Mill (fig. 13) the conglomerate may reach a thickness of 40 feet and is interpreted as a valley fill. High areas of the pre-Cretaceous surface will be either devoid of conglomerate or only very thinly mantled by conglomerate.

The composition of the conglomerate likewise will vary greatly, depending upon the source rock from which it was derived. Many Paleozoic and pre-Cambrian rock types were at the surface during basal Cretaceous time and these rocks are the parent materials of the conglomerates. The best conglomerates in central Texas are in areas in which limestones are the predominant rock. More specifically, the areas underlain by the Ordovician Threadgill member of the Tanyard formation, the Cambrian Wilberns formation, and the Cap Mountain limestone member of the Riley formation furnish the best conglomerates. Areas underlain by cherty Ellenburger limestones and dolomite have conglomerates containing cherts, areas underlain by Hickory sandstone contain abundant boulders of indurated sandstone or quartzite, and areas underlain by pre-Cambrian rocks contain much quartz, friable schist, and often decomposed granite pebbles. Chert, quartz, and quartzite are objectionable because of appearance and hardness, and friable materials are apt to decompose, leaving holes. Conglomerates desirable for building stone will therefore be limited to favorable source areas. No attempt was made to investigate these conglomerates systematically; however, during the geologic mapping of Gillespie County these conglomerates have been mapped. The most desirable conglomerate yet found lies above the Ordovician Threadgill member of the Tanyard formation and the Wilberns formation in the Lange's Mill area (fig. 13). Another promising area of conglomerate is located near Hudson Mountain in northeastern Gillespie County. Several exposures of conglomerate which appear desirable are located along Marshall Creek southeast of Cherry Spring in Gillespie County. The Paleozoic rocks in this area are of the right type to furnish a good building stone conglomerate, but the exposures are in a flat area of Travis Peak sand which largely masks the outcrops.

Description by Localities

Gillespie County

LOCALITY G-25

Location and geology.—A conglomerate is located at Lange's Mill and vicinity. A map of the outcrop is shown in figure 13. The conglomerate varies widely in pebble size from 2-foot boulders near the base of the deposit to much smaller material near the top. The pebbles consist mostly of limestone from the Threadgill member, the Wilberns formation, and the Cap Mountain limestone member. Some hard quartzite pebbles of Welge and Hickory sandstone, and very rarely a small pebble of granite and some chert, are also contained in the conglomerate. The conglomerate outcrops along the west valley wall of Threadgill Creek upstream from Lange's Mill and may be as much at 40 feet thick. Conglomerate outcrops in Threadgill Creek at intervals for several miles upstream.

The conglomerate is composed of pebbles and boulders having a very wide range in size and color. Some pebbles are of solid colors and others are variegated. The conglomerate takes a good polish and is handsome. Some porosity exists between pebbles, with holes as much as an inch in size being present.

Lampasas County

A sample of conglomerate collected from Lampasas County by C. L. Baker is composed of pebbles of the following rocks: Hickory sandstone, Cap Mountain limestone, Wilberns formation including *Girvanella* beds, Ellenburger rocks including both dolomite and calcite marbles, and a few pebbles which resemble the Marble Falls limestone. The pebbles have a wide range of color from white through various gradations of pink, gray, and brown. A few of the glauconitic pebbles have a greenish cast. The pebbles are in brownish-red matrix of sand and small limestone fragments. The conglomerate is well cemented, is without visible porosity, and takes an excellent polish. Nothing is known about the location, thickness, and amount present. When the area is mapped geologically, deposits of commercial size may be found.

Limestones

PROPERTIES

Definition and composition.—Pure limestone is composed essentially of calcite (calcium carbonate). Limestones vary widely in purity. They may contain dolomite (calcium magnesium carbonate). If the dolomite content is about 20 per cent they may be called dolomitic or magnesian limestones. When dolomites are used for dimension stone they are classed commercially as limestone. Limestone may range toward shale in composition and contain some clay and sand. Some limestones are glauconitic, others contain bituminous or carbonaceous matter, and still others may contain iron oxides and pyrite.

Limestones may be formed either in fresh or salt water and may be either of organic or chemical origin. The preponderance of limestones are formed under marine conditions. Many are composed of shells or shell fragments in a mud of ground up shell material. Other deposits are apparently devoid of shell material and may be chemically precipitated calcium carbonate.

Texture and color.—The texture of limestone is varied. Extremely fine-grained homogeneous limestones usually magnesian may be used for lithographic printing. The most common limestones are fine grained, dense, and homogeneous with a wide range in color from white to black.

Many limestones are heterogeneous, being composed of fossils or oolites mostly in a dense matrix. Oolites are concentric, laminated, rounded grains sometimes with radial structure. Similar bodies of the size of peas are called pisolites. Oolites or pisolites may compose most of some limestone or they may be a minor constituent. Fossils and fossil fragments are abundant in many limestones. The fossils may be large or small, one species or several species. Limestones are often designated by the chief fossil contained, such as rudistid, *Requienia*, crinoid, gastropod, or coral limestones for the larger fossils, and miliolid or nummulitic limestones for the foraminifera. Chalk is composed mostly of minute shells of foraminifera. Loosely cemented, fragmental, shelly limestones are called coquina.

The color of pure limestone is white. Limestones are mostly impure, containing substances which give them colors other than white. Various admixtures of carbonaceous and bituminous materials will give a range in color from light gray to black. Iron oxides produce ranges of colors in the yellows, browns, and reds.

Porosity and strength.—Limestones vary greatly in porosity and consequently vary greatly in weight per cubic foot. Some limestones weigh as little as 110 pounds per cubic foot; others which are dense and compact may weigh as much as 170 pounds per cubic foot. The physical properties of limestones will be discussed in more detail in the chapter on physical testing of building stones.

CENTRAL TEXAS LIMESTONES

Resumé.—The oldest limestones of the Cretaceous in central Texas suitable for building stone are of Glen Rose age. Hill and Vaughan[64] describe the Glen Rose limestone of the Austin area as follows:

> The Glen Rose formation outcrops on the slopes of all the numerous hills of the Edwards Plateau and forms the bluffs of Mount Bonnel and the canyon of the Colorado. The rocks consist of beds of white and yellow limestone alternating with softer beds of limestone or clay. The thickness is from 500 to 700 feet. In the northwestern part of the quadrangle, near the western boundary, the formation is thinner than at Austin, thickening southeastward.
>
> The lowest beds of the Glen Rose formation are marked by the appearance of strata of homogeneous texture, such as "magnesian" marls and hard layers in which the fossil *Requienia* occurs. The term magnesian has long been applied to certain yellow strata in these beds. The writers cannot state positively whether the strata are or are not magnesian in composition. The name "Caprotina Horizon No. 1" has also been applied to these beds, because in the earlier geologic literature the fossils now called *Requienia* were termed *Caprotina.*
>
> In nearly all complete sections the Glen Rose formation shows three marked subdivisions. The lower and upper thirds are composed of thin-bedded alternating marl and flags, usually weathering into terraced slopes; the middle third is made up of thicker and more massive beds, which weather into bluffs. Some of the beds near the base of the thicker layers are chalky in texture and carry many peculiar fossils, especially noteworthy being a foraminifer, *Orbitulina texana*, besides many casts of large mollusks. The lower portion of the formation carries much fine arenaceous material in addition to the calcareous material, and its indurated and unindurated beds do not occur in such uniform alternations as do those of the upper third. For instance, there will be 10 or 12 feet of soft, friable material and then a thin layer (less than a foot) of indurated stone. In weathering this results in wide terraces with steep slopes.
>
> The yellow "magnesian" strata also increase in thickness in ascending series, and become very conspicuous in the middle portion, often being from 5 to 15 feet in thickness, as seen in the bluffs of Mount Bonnel near Austin. These limestones are soft and of a cream or brownish-yellow color, and alternate with strata of marls similarly constituted, and are sometimes accompanied by pockets or nodules of calcite, aragonite, strontianite, celestite, and epsomite.
>
> The upper third of the formation, as seen at the top of Mount Bonnel, presents alternations of friable marls and hard limestone strata. The limestone strata usually average less than a foot in thickness. These alternations occur with greatest regularity and persistence. Clay is the chief accessory of the calcareous beds. The marls are soft and laminated and are composed largely of minute shell fragments, giving the beds a distinctly granular, oolitic character. They have little clay and imbibe moisture very freely.

While possessing no great agricultural possibilities, the basal or alternating beds are capable of producing valuable building material. Some of these have rich "magnesian" buff-yellow colors, while some of the white unlaminated limestones suitable for carving resemble the Caen stone of France, which is imported into this country.

[64]Hill, R. T., and Vaughan, T. W., Description of the Austin quadrangle: U.S. Geol. Survey Geol. Atlas, Austin Folio (No. 76), p. 3, 1902.

Hill and Vaughan (p. 3) measured a section of the Glen Rose in the vicinity of Lohmann Ford, Travis County, as follows:

[Partial] section from top of high hill south of Round Mountain and east of road from Bee Caves to Lohmann Ford on Colorado River.

	Feet
Glen Rose formation:	
38. Shaly limestone; not very fossiliferous	10
37. Alternating hard and soft strata of limestone; some thin slabs about base; not fossiliferous	15
36. Alternating hard and soft yellowish limestone; not very fossiliferous	35
35. Shaly limestone, fossiliferous; contains a few individuals of *Cardium mediale* and a few other species	4
34. White limestone; breaks easily	15
33. Marly material, forming a terrace	10
32. Alternations of soft argillaceous or marly limestone with harder thin layers of purer limestone (4 hard and 3 soft layers)	30
31. Slope and shelf; fossils at top	15
30. Hard, nodular limestone; contains *Nerinea* fragments	5
29. Slope and shelf	14
28. Thin, hard ledge	1
27. Slope, very gentle—rather a shelf	15
26. Bed of *Monopleura* in hard, yellowish limestone—thin, a foot or two.	
25. Hard, perforated limestone	2
24. Alternating thin, hard layers and soft, thick layers; the thin layers 6 inches to 1 foot, the soft 3 to 4 feet	20
23. Soft, chalky, argillaceous stuff, only a few feet.	
22. Ledge of hard, yellowish, perforated limestone, 2 feet; hard ledges of limestone, 8 feet	10
21. Small, hard ledge, 1 or 2 feet.	
20. Soft, argillaceous limestone, marly; forms a slope	10
19. Shelf above, ledge below, rises	10
18. Soft, chalky, argillaceous limestone with *Exogyra texana* at base, with harder layers that form shelves—11 hard ledges. Twenty feet from the top of these beds the hard ledge is honeycombed by solution, and is arenaceous. In the lower 20 feet numerous fossils occur: *Tylostoma pedernalis, Cardium mediale, "Goniolina,"* etc.; also horizon of *E. texana*. Thickness of series	60
17. Hard ledges of honeycombed (perforated) limestone. The limestone, hard, yellowish, contains many poorly preserved calcitized fossil shells, largely the remains of nerineas	30
16. Hard ledge of limestone; many *Cardium mediale*	5
	Feet
15. Soft, argillaceous, chalky limestone	5
14. Ledges, 6 inches to 1 foot thick, with soft, shaly layers between	20
13. Soft limestone	20
12. Hard ledge	2
11. Soft, chalky, argillaceous layer	10
10. Ledge of hard, brownish or yellowish limestone, containing embedded sand grains	5
9. Soft, chalky, argillaceous limestone, with an occasional hard ledge. Hard ledge 2 feet thick 15 feet above base. In the upper part of this marly bed fossils are very abundant. *Cardium mediale, Tylostoma pedernalis,* many echinoderms, *Pseudodiadema texana, Nerinea, Ostrea,* etc.	35
8. Ledge of hard, yellowish limestone	5
7. Slope, underlain by soft, chalky limestone	25
6. Arenaceous ledge, a few feet.	
5. Soft ledge with many *Monopleura*, a few feet.	

Nine different Glen Rose limestones have been sampled during the building stone investigation. The majority of the samples contain microfossils and some contain oolites. One stone is composed of large fossils, possibly *Requienia*. Only two samples contain recognizable dolomite crystals.

Above the Glen Rose limestone is the Walnut clay, a 10 to 50-foot clay bed containing abundant *Exogyra texana* and *Gryphaea marcoui*. In northern Travis County and southern Williamson County a limestone member supposedly in the Walnut clay thickens it to about 160 feet. Two *Exogyra* clays are here separated by about 125 feet of limestone known as the Cedar Park member. This member may actually be equivalent to rocks elsewhere mapped as Glen Rose limestone. The Cedar Park member has been extensively quarried and furnishes two types of excellent limestone. One is a light-colored oolitic stone sold under the trade name of "Cordova cream," and the other is a light-colored limestone filled with fossil imprints, sold under the trade name of "Cordova shell."

Five localities probably in the Cedar Park limestone member have been sampled. Extensive mapping would be necessary to establish definitely that all these samples are from the Cedar Park member.

The samples are predominantly calcite limestone with only one containing some dolomite. Oolites and similar small rounded bodies are abundant in most of them.

Above the Walnut formation is the Comanche Peak limestone, a white, chalky, in part nodular limestone 25 to 50 feet thick. In Gillespie County a few persistent beds at the top of the Comanche Peak limestone have been extensively quarried for buildings in Fredericksburg and for local farm residences. The limestone used is good and shows little deterioration from weather. Throughout most of the Comanche Peak limestone outcrop area, however, little limestone of value for building is present.

Above the Comanche Peak limestone is the Edwards limestone, a bedded, hard, cherty limestone. Hill and Vaughan (p. 4) describe the Edwards limestone of the Austin area as follows:

The Comanche Peak limestone is the base of a thick group of limestones consisting of the Comanche Peak and Edwards formations. The upper formation contains a large number of flint nodules with vast quantities of *Rudistes* and aberrant *Chamidae,* and was called by Shumard the Caprina limestone.

This formation is the most conspicuous and extensive in the Texas-Mexican region. It is composed mostly of limestone strata, but there are some marly layers. It shows slight variation in color, composition, texture, and mode of weathering. In general the beds are whitish, although layers of buff, cream, yellow, or dull gray are frequent. These colors depend much upon weathering. In composition many of the beds are as nearly pure carbonate of lime as can be found in nature, but some have small admixtures of silica, epsomite, chloride of sodium, and perhaps other salts as yet undetermined. Occasional bands of soft brownish-yellow stone are intercalated with the limestone. These bands are popularly called "magnesian," and are composed largely of exceedingly fine-grained siliceous material, like tripoli. As these beds often contain flints, the silex may be of organic origin. Clay is absent except as a minor constituent in the few marly layers. Iron is sparingly present as pyrites, and is revealed by the red color of the clay that weathers out of a few beds. Exceedingly fine siliceous particles occur, especially southward from Comanche County—but no sand grain, pebble, bowlder, lignite, or other undoubted piece of land-derived débris has ever been found.

The limestones vary in degree of induration from hard, ringing, durable strata to soft, pulverulent chalk that crumbles in the fingers and resembles very much the prepared article of commerce. Some of the beds are coarsely crystalline, with calcitized fossils, and are susceptible of high polish. The beds also vary in texture. Some of them are porous and pervious, while others are close grained and impervious. Some are homogeneous throughout; others have hard and soft spots, the latter dissolving by the percolation of underground water and constituting what is popularly termed "honeycombed" rocks. The harder spots in some cases seem to be in process of induration, suggesting a step in the formation of flints. The holes in the honeycombed layers often represent what were once spots containing soluble salts of iron and other accessory minerals.

The formation can usually be distinguished by the immense quantity of flint nodules embedded in and between the limestones and scattered over the surface everywhere. These are of many shapes; some are fusiform, like elongated roots; others are knotty, like warty potatoes; others are parts of extensive sheets of very flat lenses. They vary in size from that of a hen's egg to a foot or more in diameter. They also vary greatly in color. On fresh fracture some are almost jet black; others are light blue, gray or opalescent; still others are delicate pink in color. There is some, but not conclusive, evidence that each particular kind of flint occupies a definite horizon.

In most cases the Edwards limestone may also readily be distinguished by the peculiar aberrant mollusks of the genera *Monopleura, Requienia,* and *Radiolites*—bivalve fossils which have cornucopiate form, suggesting a resemblance in shape to the horns of cows, goats, and sheep.

The formation is stratified into a succession of massive beds accompanied by very few flaggy and marly layers. Some of the strata are harder than others and project beyond the softer layers in the profile of the hills as overhanging shelves; others are soft and erode very rapidly.

Hill and Vaughan (pp. 4–5) measured sections of Edwards limestone as follows:

Section of bluff on Barton Creek 1 mile above Barton Spring, Travis County.

	Feet	Inches
Edwards limestone:		
49. Nodular limestone full of requienias (first requienia bed)	3	0
48. Nodular limestone, nodules as large as one's head	2	0
47. Hard, chalky limestone	3	0
46. Thinly laminated limestone (the so-called "lithographic flags")	8	9
45. White, sublaminated, chalky limestone. The lower part of Nos. 45 and 46 contain many fossils—*Exogyra texana, Pholadomya knowltoni,* etc.	8	5
44. Nodular limestone, no requienias	1	0

	Feet	Inches
43.* Nodular limestone with many requienias (second requienia bed)	3	9
e. Laminated limestone	1	0
d. A series of hard limestone ledges (eight in number), separated by the thinly laminated layers. There are some flints, about as large as a man's fist, *Radiolites* and *Chondrodonta munsoni*	45	8
c. Flaggy layer with discoidal flints	2	4
(29)b. Hard limestone, forming a shelf along this portion of Barton Creek and its bottom at the bridge below, eroded into deep pot holes. The lower 2 feet of this layer contains very large blue flints, often 1 foot across. Some of them are oval, others flattened out and very irregular in outline. The upper part of bed contains small flints	12	8
a. Limestone ledges, with some flattened flints. All of the flints in this section belong to the blue variety	11	0
Base of *a* is Barton Creek bed.		
Total thickness of strata in bluff	171	11
[Total Edwards	102	7]

Section of Deep Eddy Bluff, south of the Colorado River, west of Austin.

	Feet	Inches
43. Nodular limestone with requienias at top (the second requienia bed of the Barton Creek section.		
42. Limestone ledges	5	0
41. Limestone ledges containing requienias. The three layers above described form a slope to the top of the hill (or bluff) above the face proper of the bluff	1	0
40. Ledge of hard limestone, 10 inches above basal sheet flint. The upper part of the ledge contains rather small nodular flints	15	0
39. Limestone weathering out and giving rise to a good deal of red clay, apparently representing the zone of calcitized fossils found in the high bluff above McGill's Ford	6	6
38. Massive, thick ledges of limestone, detail not exposed	23	8
37. Soft, white, arenaceous limestone	2	2
36. Soft, arenaceous limestone	3	10
35. Ledge of limestone, rather soft, emitting odor of petroleum	2	10
34. Chalky limestone, forming little caves, composed of a good many small ledges, discoidal flints at top	4	0
33. Hard limestone, emitting odor of petroleum under blows of hammer. Texture of limestone rather mealy. Nodular flints, occasional discoidal flints in top	2	1
32. Two thin ledges of limestone, layer of sheet flint in top	1	2
31. Ledge of thick, massive limestone	5	0
30. Hard, yellowish limestone	2	0
29. Hard, thick, massive ledge of siliceous limestone, ringing under blows of hammer. At the base there is a layer, about 9 inches thick, of opalescent, pinkish or brownish flint. Apparently the limestone is being converted into flint by replacement, and the process has not yet been completed	6	0
28. Soft, chalky limestone, dissolving and forming small caves	3	0
27. Soft, chalky limestone with very large (may be 1 foot long), irregularly shaped blue flints at top	2	3
26. White, chalky limestone, apparently siliceous; zone of flint near the top. The flints blue, discoidal and tending to form sheet	6	8
25. Massive ledge of hard, bluish limestone	7	0
24. Very hard limestone	0	6
23. A layer of enormous blue flints, in some places over 1 foot thick	1	0
22. Thick, massive ledge of limestone, rather soft, yellow in color, and slightly arenaceous	5	5
21. Ledge of hard, yellowish limestone with a zone of flints tending to form a sheet at base	1	4
20. Soft, white, slightly arenaceous limestone, composed of thin ledges; upper 2 feet, middle 4 feet, lower 1 foot	7	0

*The beds in the Barton Creek section below 43 cannot be correlated layer for layer with the Deep Eddy Bluff section; therefore numbers are not used in the description of the former section for beds below the one numbered 43 except the one lettered *b*, which is equivalent to 29 of the section below.

	Feet	Inches
19. Soft, yellowish or whitish limestone with layer of flattish, bluish flints forming a sheet at top. This is really three ledges; upper ledge, with flints at top, 2 feet; middle containing concretions of calcite in lower part, 4 feet; lower ledge exposed at low water, 1 foot	7	0
Total, Deep Eddy section	121	5

Section of bluff at mouth of Bee Creek.

	Feet	Inches
Limestone slope, detail not exposed	11	0
23. Layer of enormous blue flints	1	0
22. Arenaceous limestone	5	5
21. Hard, yellowish limestone with sheet flint at base	1	1
20. Yellowish, rather hard limestone, somewhat siliceous; thin band of chalky limestone at top, calcite concretions near base	6	0
19. Sheet flint at top (sheet flint at top of lowest ledge of Deep Eddy Bluff); three ledges of limestone: upper, 1 foot; middle, 2 feet 6 inches; lower (containing calcite concretions), 3 feet	6	6
18. Sandy limestone, with two zones of nodular flints near middle; sheet flint at base; mass of requienias just above the sheet flint	10	0
17. Soft, yellow, calcareous sandstone, a part of the preceding ledge, about	3	0
16. Yellow, cherty limestone, about	0	6
15. Three or four ledges of rather soft, whitish or yellowish limestone; the upper ledge containing a great mass of requienias, the others fewer	8	1
14. Solid, white limestone, granular, not very hard; contains a great many requienias near the top	6	11
13. Yellow, arenaceous limestone	4	0
12. Blotched, arenaceous limestone	3	8
11. Soft, yellow, arenaceous limestone	2	0
10. Hard, yellowish, granular limestone, with shell fragments, gray on fresh exposure	1	6
9. Soft, yellow, arenaceous limestone or calcareous sandstone	2	4
8. Ledge of nonindurated, granular limestone, with indurated blotches, which are structureless and flinty looking	1	0
7. Ledge of white, rather soft limestone, with many very irregularly shaped flints in a zone about the middle of the ledge. The flints are mostly small, bluish in color, and do not show concentric banding; about	3	0
6. Ledge of white, rather soft limestone, no flints, a few fragmentary fossils	2	6
5. A soft, arenaceous ledge. The lower 1 foot 10 inches is a subledge. In the upper part (near top) are concretionary bodies that in form resemble flints, but are not flints in texture. These bodies are hard, apparently siliceous, and contain white blotches, some of which appear to be of foraminiferal origin	5	5
4. Hard limestone, whitish or bluish, without flint; not fossiliferous	4	0
3. Arenaceous limestone, has a tendency to lamination, but in the ledge the laminated character is not always evident. The upper part of the ledge by solution becomes porous. The rock has a considerable absorbent power for water, and has a dark (wet) appearance due to contained water	5	9
2. Thick ledge of white limestone, not very hard, oxidizing yellow from contained iron. Contains a large number of irregularly shaped flint nodules. These may be as much as 1 foot long, but usually are rather small—3 or 4 inches in length. They are bluish in color and have a concentrically grained structure, resembling the graining of pine wood. Their long axes are not always parallel to the bedding planes of the limestone, an important exception to the usual position of the flints relative to the stratification of the limestone	5	9
1. Ledge of yellowish or whitish limestone, without flints, in a thin layer, about 6 inches thick; at the top of this ledge there is an enormous number of *Requienia texana*	4	0
Total, Bee Creek section	104	8

	Feet	Inches
The thickness of the Edwards limestone exposed along bluffs of the Colorado between Austin and Bee Creek is as follows:		
Bluff on Barton Creek, beds 49 to 43	29	11
Deep Eddy Bluff, beds 42 to 24	99	8
Bluff at mouth of Bee Creek, beds 23 to 1	104	8
Grand total	234	3
Total thickness, including the 70 feet or more of the lower part of the formation preserved on the summits of the plateau, about	300	

Beds 49 and 43 are important marbles which have been seen at many places in the Austin area and are probably continuous for a considerable distance. In one area the upper bed (49) is a *Turritella* marble which possibly exceeds the *Requienia* marble in beauty. Beds 38, 31, 25, 24, 15, 14, and 4 of the above sections may all be good building stones. It was not possible to correlate all of the samples taken with the beds listed. Beds change thickness and composition laterally, and a few miles away a section of the same rocks might be noticeably different. To determine all of the good building stone beds in this section would require careful mapping and the measuring of numerous sections.

Thirteen samples of Edwards limestone were collected during the building stone investigation. Seven of these take an excellent polish and are classified as commercial marbles, two take a dull polish, and four do not take a polish. Two samples are composed predominantly of large fossils, five samples contain abundant microfossils and some larger fossils, four samples are predominantly fine-grained calcite, one sample contains both dolomite and calcite, and one sample is somewhat oolitic.

Above the Edwards limestone is the Georgetown limestone which mostly is unsuited for building stone. A few local limestone beds in it may be usable as "field stone" in local construction. No Georgetown limestone samples were collected.

Following the Georgetown limestone successively are the Grayson marl (Del Rio clay), Buda limestone, Eagle Ford shale, Austin chalk, and the Taylor formation. No Buda limestone of building stone quality was seen. The Austin chalk in general cannot be recommended as a building stone. One sample was collected from an old quarry in the chalk. The stone in part might be used, but variation in composition and physical properties exists. Stone from this locality would weather differentially, producing an unsightly appearance.

Two samples of a novelty stone were collected from Travis County. One of these is a calcite-cemented tuff (serpentine) flanking Pilot Knob, which is an old Cretaceous volcano composed of nepheline basalt (limburgite) flanked by tuffs. Another sample of similar material was collected on Barton Creek from a limited exposure associated with a small limburgite mass. The locations of the following described limestones are shown in Plate 1.

Glen Rose Limestone

Description by Localities

Blanco County

LOCALITY BL–3

A deposit of Glen Rose limestone is located a few hundred yards east of the Blanco-San Antonio highway and along the north bank of Little Blanco River. It is northeast from the store at Twin Sisters. The limestone outcrop forms a vertical cliff along Blanco River. The top bed, about 12 inches thick, is hard, iron stained, and highly fossiliferous. The next bed, about 18 inches thick, is a white, fossiliferous, attractive limestone. Beneath it is about 4 feet of hackly limestone of poor quality, and under this is a nodular limestone of no value. The 18-inch bed is the only one of value as a building stone, and it is of value only locally. It was used in the store at Twin Sisters, built in 1882, and the original tool marks are retained on exposed surfaces of the limestone, indicating favorable resistance to weathering.

The limestone is composed entirely of calcite. It is crowded with fossils, many of the microforms of which are intact. Some oolitic development has taken place with addition of calcite layers to fossil fragments.

LOCALITY BL–4

A deposit of Glen Rose limestone is located 3.3 miles north of Blanco along the Blanco-Johnson City highway. Three feet of very hard, light brown limestone is present with sandy clay both below and above it. The limestone varies between about 2 and 4 feet in thickness. The old Blanco County courthouse, built out of this stone before 1890, is still in an excellent state of preservation.

The limestone is of a light gray color and is slightly speckled by light brown millimeter-sized specks. A slight variation in color and texture makes the bedding visible.

The limestone is composed of fine-grained calcite. It is made up almost entirely of fossils and fossil fragments which give it a granular appearance. Some oolites are present. The limestone is of value for local building.

LOCALITY BL–5

A deposit of Glen Rose limestone is located just south of the intersection of the San Antonio and the Austin-Johnson City highways. It is just west of the San Antonio highway and about 7 miles from Johnson City. The limestone is white and somewhat porous. The bed being quarried is 14 inches thick and is practically free of joints. Some blocks have been quarried that are 16 feet long. The limestone is of two similar shades of light gray which give it a slightly mottled appearance. A few millimeter-sized brown spots are scattered throughout the stone. It is composed of fine-grained calcite. A few fossils and fossil fragments are present. The limestone is used for local building and is of value for this purpose.

Travis County

LOCALITY T–11

A 4-foot bed of Glen Rose limestone is exposed a short distance up Little Barton Creek from its mouth. The outcrop is about 12 miles from Kouns which is the nearest point on a railroad. Upstream a short distance several other ledges apparently of good stone alternate with beds of soft stone. Beneath the building stone ledge are marly clays containing *Orbitolina, Porocystis,* and many other Glen Rose fossils.

The limestone is of a dirty brownish-gray color. It has occasional slightly darker colored areas in it which may be filled burrows. The texture is rather uniform, and very small dark-colored grains are well distributed through it.

The limestone is composed of dolomite bands containing a small amount of calcite alternating with layers of very fine-grained calcite containing abundant rhombs of dolomite. The dolomite rhombs range up to about 1/10 of a millimeter in size. A small amount of 1/10 of a millimeter-sized sand is also present. Fossil fragments are scarce. The limestone is not pleasing in color but may otherwise be of value for local building.

LOCALITY T–13

A fossiliferous Glen Rose limestone is located south of Barton Creek and is about 11 miles from the nearest point on a railroad, which is at Kouns. The limestone bed is about 1 foot thick and is a novelty stone containing abundant rudistid-like mollusks. It outcrops on a gentle slope.

The limestone is composed of large fossils, mostly *Chondrodonta* and rudistids. The matrix is compact, contains some fossil fragments, and varies in color from light gray to light brownish gray. The rudistids are in part porcellaneous white and contrast nicely with the rest of the stone. The rudistid living chambers are in part hollow and are somewhat unsightly.

The limestone is composed essentially of calcite and is crowded with large fossils, microfossils, and fossil fragments. The calcite varies from very fine grained to coarsely crystalline. The sample obtained is not pleasing in color. The fossils are rather attractive, but the stone is limited in amount.

LOCALITY T–17

A deposit of Glen Rose limestone is located about 5½ miles from the center of Austin and is about 500 feet southwest of the Bee Caves road. It is located on a slope just south of a small branch. The limestone has been quarried along the slope for a distance of several hundred feet. The ledge quarried is about 18 inches thick. It has a foot of shale above it followed by another foot of limestone which might be of value. The surface slopes gently, and a considerable area of stone is present with little overburden above it.

The limestone is of a uniform, light gray color with a suggestion of a brownish tint. It is fine grained, even textured, and has only a few small fossil fragments in it.

The limestone is composed essentially of very fine-grained calcite crowded with microfossils. Many of the fossils are distorted, having apparently been so abundant that during compaction of the limestone the weaker ones were collapsed by the stronger ones. The limestone is attractive and is of value for local building.

LOCALITY T–22

A deposit of Glen Rose limestone northeast of the Bee Caves road is located about 5 miles from the center of Austin. It is situated midway on a steep slope and is about 200 feet from the road. The limestone bed, which is about 4 feet thick, has been quarried. It is about 20 feet beneath a clay bed containing abundant *Exogyra texana* and *Gryphaea marcoui*. Another 2-foot ledge of limestone is situated 20 feet beneath the 4-foot limestone and contains small dark particles throughout which may be oyster shell fragments.

The limestone is of a very light brownish-gray color with numerous, evenly distributed, small shell fragments which vary in color from light gray through dark gray to almost black. A few quarter-inch sized light brownish-gray mud balls are present. The mud balls are in part of very soft material which tends to disintegrate. Close inspection reveals that the limestone is composed of about equal amounts of light brownish-gray elliptical bodies and light gray matrix.

The limestone was not thin sectioned, but a staining test indicates that it is predominantly composed of calcite with a small amount of dolomite. A few microfossils and much fossil detritus can be seen with a hand lens. The limestone is situated along a steep slope, necessitating excessive stripping. It contains some mud balls which disintegrate readily; consequently, this limestone cannot be recommended as a building stone.

LOCALITY T–27A

A bed of Glen Rose limestone has been quarried just north of the lower Bull Creek road and just west of Dry Creek. The deposit is about 1½ miles from a railroad. The limestone bed ranges between 20 and 22 inches in thickness and is covered by only a very thin veneer of overburden. The same bed has been extensively quarried on the opposite side of Dry Creek to the north and east.

The limestone is fine grained, somewhat mottled, and of a light buff color. The grain size varies somewhat, with areas of extremely fine-grained limestone scattered through a groundmass of fine to medium-grained limestone.

The limestone is composed essentially of calcite in grains up to about 1/15 of a millimeter in size. A small number of fossil fragments are present. The limestone is of a pleasing color and is a very satisfactory stone for local building.

LOCALITY T–32

A deposit of Glen Rose limestone located about 1 mile up Bull Creek from the lower Bull Creek road is about 4½ miles by road from the nearest railroad. The bed sampled is about 8 feet thick. It is one of a series of thick beds of Glen Rose limestone exposed in a bluff estimated to be 75 feet high. The stone varies somewhat from bed to bed, but many beds are present very similar in quality to the one sampled.

The limestone is rather porous and granular. It is light gray and contains numerous circular to irregular dark gray areas which are probably filled burrows.

The limestone was not thin sectioned, but a staining test shows it to be composed predominantly of calcite. Some microfossils and possibly some oolites can be seen with a hand lens. Selected beds of this limestone may be of value for building stone.

Cedar Park Limestone

Description by Localities

Travis County

LOCALITIES T–2 AND T–3

A deposit of limestone, probably the Cedar Park member of the Walnut, is located at the head of Cypress Creek. The outcrop forms a steep slope, and the following section was measured along it, using a hand level.

Section of limestone near head of Cypress Creek, Travis County.

	Thickness Feet
Thin-bedded limestone (possibly of use for pitched face stone)	4
Hard limestone of fine grain and uniform texture without a bedding break (of use for sawed stone)	5
Same as above without a bedding break	18
Limestone which weathers to a honeycomb surface (of little use as a building stone)	5
Rather uniform, fine-grained limestone (possibly of use for sawed stone)	6
Nodular, rather massive limestone (of no value)	12

Above this section are softer materials which form a bench. The bench has a low slope and rises an average of 10 feet in 200 feet. The stripping necessary to obtain stone suitable for sawing would, therefore, range from 4 feet at the edge of the steep slope to 14 feet at a distance of 200 feet from the edge and a correspondingly greater thickness with increased distance. The two most desirable ledges of stone are the 18-foot bed and the upper 5-foot bed. Two samples were collected, one from the 18-foot bed (T–2) and one from the 6-foot bed (T–3).

T–3 varies between pasty gray and light gray in color and has some small splotches of light brown scattered through it. Fossils and fossil fragments are present. The fossils take a brilliant polish, the pasty gray-white portion of the stone takes a dull polish, and the light gray portion remains dull.

T–2 is composed of calcite which is mostly fine grained. Fossil fragments are rather numerous. T–3 is composed of fine-grained calcite with small 1/15 of a millimeter-sized dolomite rhombs abundantly distributed throughout. Fossil fragments are present but are not abundant.

A large amount of thick-bedded limestone is present in the deposit. The limestone should be of value as a commercial building stone.

LOCALITY T–5

A limestone deposit is located about 0.3 mile west of the Austin-Burnet highway at a point 2.2 miles northwest of the Southern Pacific Railroad crossing between Spicewood Springs and Duval. Two beds, the top one 7 feet thick and the bottom one 4 feet thick, were sampled. Downstream another hard, massive limestone bed overhangs the stream from 20 to 30 feet. Still farther downstream is a cliff of nodular limestone containing celestite geodes and at the base an *Exogyra texana*-bearing clay. A short distance above the building stone ledges is another *Exogyra texana* bed. The building stone beds are, therefore, in the Cedar Park member of the Walnut formation.

The limestone is white to light translucent gray in color. It is composed chiefly of fossil fragments which are of colorless calcite. It takes an excellent polish and commercially would be classified as a marble. Thin panels of this stone should be translucent in spots and very attractive in appearance.

Under the microscope the limestone is seen to be composed of calcite, some crystals of which are several millimeters in size. Large fossils and fossil fragments are abundant and some microfossils are also present. The limestone is of good quality and should be of value as a building and ornamental stone.

LOCALITY T–30

Location and geology.—A limestone deposit is located about 3 miles northwest of Oak Hill and a short distance northeast of the Oak Hill–Bee Caves road. The nearest railroad to this deposit is at Kouns, a distance of about 9 miles. A large number of small quarries have been opened along limestone beds in this area. A road cut exposes 3.5 to 4 feet of limestone of good quality. Just above the limestone is a bed with a somewhat irregular top surface which is bored to a uniform depth by some organism. The bored layer is prevalent in this area and may indicate a disconformity. A large amount of white limestone is present with only a shallow overburden above it.

Megascopic description.—The limestone is of a light brownish-gray color which varies slightly in intensity in different beds. The bedding is not well marked and the color difference is gradational. The limestone is fine grained and takes a fairly good polish.

Microscopic description.—The limestone is composed of rounded, dark-colored objects some of which are definitely fossils and others of which show no organic structure. These objects are essentially very fine-grained calcite and are in a groundmass of slightly coarser grained calcite which contains numerous microfossils and fossil fragments.

Recommendations.—A large amount of limestone from this locality has been used in Austin, and some has been shipped to near-by cities. The stone is very attractive, is of good quality, and is of value for pitched face stone.

LOCALITY T-34

Location and geology.—A limestone deposit is located a short distance west of the railroad and just north of Waters Park. The limestone is fine grained and has a granular appearance. With the aid of a hand lens the grains are seen to be rounded and to have very little the appearance of organisms. They also do not closely resemble oolites. A few dark-colored fossil fragments in the stone may be *Exogyra texana*. The limestone contains a few thin veins and some markings resembling reed impressions. A small amount of the limestone has been quarried. The age of the limestone was not definitely determined.

Megascopic description.—The limestone has a uniform, fine-grained structure and a uniform, light gray color. It is granular and in general has much the appearance of sandstone. A small amount of porosity is present.

Microscopic description.—The limestone is composed essentially of coarse-grained calcite which is crowded with small rounded objects many of which appear to have an organic structure. These objects are dark colored and are composed essentially of very fine-grained calcite. A few microfossils are present.

Recommendations.—The physical properties indicate that this is an unusually strong and durable limestone. It is of a pleasing color. A large amount of limestone is available, and it is a very desirable building stone.

LOCALITY T-37 (TEXAS QUARRIES)

A deposit of Cedar Park limestone situated on the Travis-Williamson County line has been extensively quarried. The deposit is located about 2½ miles west of Cedar Park, and a railroad spur extends to the quarry.

Most of the limestone has been produced from two quarries. The westernmost one, which has been most recently operated, exposes a 6.5-foot bed of oolitic, cross-bedded limestone with 3 to 20 feet of marly and impure limestone above it. Where the overburden is thin, solution caverns are abundant.

The easternmost quarry also has 6.5 feet of oolitic limestone exposed in it. Beneath the oolitic limestone is 0 to 4 feet of shell limestone which has been widely used. The shell limestone thickens to the south.

The oolitic limestone is predominantly cross-bedded throughout the deposit. Casts of tree trunks have been found in it and holes and other imperfections are present. The oolitic limestone bed is made up of small fossils, fossil fragments, and oolites deposited by current action in much the same manner as quartz grains are deposited to form sandstone beds.

The shell limestone is highly porous and is composed of numerous casts of pelecypods and gastropods, among which an ornate species of *Trigonia* forms the most spectacular casts. The shell bed was formed *in situ* and apparently was preserved from destruction by the bar-like oolitic limestone bed which formed above it.

A large amount of limestone remains between the two quarries, but 20 feet or more of stripping will be necessary before it can be quarried. The overburden is composed of blue marl ranging up into a nodular limestone. Where weathered, the marl is a yellowish brown. The marl contains many pelecypods and gastropods, among which are abundant *Exogyra texana*.

The oolitic limestone is sold under the trade name of "Cordova cream" and the shell limestone is sold under the trade name "Cordova shell." A photograph of a thin section of the oolitic limestone (Pl. 6) shows the texture of the stone and that it is composed predominantly of microfossils, fossil fragments, and oolites.

About 2½ million cubic feet of limestone has been produced at this locality, and it has been widely used throughout the United States and Canada. The most outstanding monument made of it is the San Jacinto Memorial near Houston. It has been used in more than 60 post office buildings throughout the United States, some of which are located in the following cities: San Antonio, Texas; Alexandria, Louisiana; Newbern, North Carolina; Vicksburg, Mississippi; Provo, Utah; and Sarasota and Jacksonville, Florida. Courthouses built of this stone are those at Austin, Travis County, and Beaumont, Jefferson County, Texas; and Chickasha, Grady County, Oklahoma. Several buildings are made of this limestone at Baylor University, Waco, Texas; and at The University of Texas, Austin, it was used in the Texas Union, Hogg Memorial Auditorium, Texas Memorial Museum, Architecture Building, and Music Building. Among other buildings built entirely or partly of this stone, the following may be mentioned: dormitory for girls, A. & M. College, Stillwater, Oklahoma; John Gaston Hospital, Memphis, Tennessee; Fitzsimmons General Hospital, Denver, Colorado; Santa Fe Railroad station, Oklahoma City, Oklahoma; E. L. Doheny Jr. Memorial Library, University of Southern California, Los Angeles, California; City Hall, Houston, Texas; Texas State Highway Building, Austin; May Company department store, Los Angeles, California; the interior of the Central Methodist Episcopal Church, Brooklyn, New York; and trim on the First Congregational Church, New York, New York. The Victory Memorial, Pelham Bay Park, Bronx, New York, is reportedly the largest free standing monolithic column in the world and is made of limestone from the Texas Quarries site. So far this limestone has been used in 34 states. Many dwellings in Austin are built of the oolitic and several of the shell limestones. The soft cream color of the limestone makes it admirably fitted for this use, and houses built of it are among the most attractive in the city.

Comanche Peak Limestone

Description by Localities

Gillespie County

The Comanche Peak limestone of Gillespie County ranges up to about 30 feet in thickness. The lower part is a marly nodular limestone and the upper part is a well-bedded, soft, easily worked limestone. The upper well-bedded portion is only a few feet in thickness and is composed of beds ranging from about 6 inches to a foot in thickness. Up to about three beds are usable for building stone in the southern part of the county. In the northern part of the county these beds become more marly and sandy and are of little use for building stone.

The Comanche Peak limestone forms a steep scarp throughout its outcrop area in this county and the building stone ledges are located at the upper break in slope. The stone has been widely used in Gillespie County for building, and small quarries are legion at the upper break in slope of the scarps and mesas. Some of the mesas near Fredericksburg have only a thin layer of flinty Edwards limestone above the building stone layer of the Comanche Peak limestone. Samples of this limestone were not collected for physical testing.

Williamson County

LOCALITIES W-1, W-2, AND W-3

A deposit of limestone is located on the southeast side of Lake Creek near its headwaters and 2 miles airline northeast of Jollyville. It is 1 mile south of a railroad, but at present there is no road connecting it with the railroad except by a roundabout route. A quarry face several hundred yards long was opened many years ago. The limestone outcrops as large smooth surfaces on which an interlacing of filled burrows can be seen. The lower portion of the bed is somewhat more free of the filled burrows and is a somewhat more uniformly colored stone. The age of the limestone was not determined, but it has some characteristics which suggest that it might be the Comanche Peak limestone.

The upper portion of the limestone is uniformly fine-grained and has numerous gray, filled burrows in a groundmass of light gray. It takes a dull polish. The middle portion of the limestone is uniformly fine grained and is almost of a uniform, light gray color. A very slight variation in color gives the rock a slightly clouded appearance.

The upper portion of the limestone was not thin sectioned, but a staining test shows that it is composed of about equal amounts of fine-grained calcite and dolomite. The middle portion of the limestone was not thin sectioned, but a staining test reveals that it is composed predominantly of calcite and a small amount of dolomite.

The limestone contains filled burrows which produce an attractive pattern in the stone. A large amount of limestone is present. Physical tests should be made to determine if the stone is of value.

Edwards Limestone

Description by Localities

Burnet County

LOCALITY BU–23

A deposit of Edwards limestone is located about 3 miles north of Burnet along the Lampasas highway. A limestone with pink bands in it is situated near the crest of a flat-topped ridge capped by Edwards limestone. It is in thin beds, none of which is more than 18 inches thick. A section measured from the top of the Walnut clay, which is well exposed in a road material pit near the foot of the ridge, shows the presence of about 35 feet of nodular Comanche Peak limestone, followed by about 60 feet of beds alternating between hard crystalline and soft pulverent limestones of Edwards age. The pink-banded stone is about 60 feet up in the Edwards limestone. Just above this is a 1-foot bed of highly fossiliferous, somewhat porous limestone which is light colored and very attractive in appearance.

The limestone is of a cream color and has widely spaced pink bands in it. One side of these bands is rather sharp while the other grades uniformly into the cream-colored limestone. The limestone has a very fine texture and only a small number of millimeter-sized light brown specks are present.

The limestone is composed of fine-grained calcite which is in part clouded. Fossil fragments are not very abundant. A few large crystals of calcite are present and in part may be portions of fossils. The stone is attractive but may not be very abundant. It is chiefly of value as an ornamental stone.

Travis County

LOCALITY T–4

A deposit of limestone is located about 4 miles by road west of Jollyville and near the headwaters of Cypress Creek. The limestone is fine grained and contains some fossils. Seven to 10 feet of limestone is exposed and the base is covered by recent material. Immediately above the limestone is a 3-foot bed of rudistid-bearing, cavernous, chert-free limestone. This limestone is either the Comanche Peak limestone or a chert-free portion of the lower Edwards limestone.

The limestone is light brownish-gray and of a uniform, fine-grained texture. It is compact and takes a dull polish. A few small fossil fragments are present.

The limestone is composed of about equal amounts of calcite and dolomite. The dolomite rhombs range up to about one-fifth of a millimeter in size. The limestone is of good quality and is probably of value as a building stone.

LOCALITY T–7

A deposit of Edwards limestone is located about 1.5 miles west of Manchaca along Bear Creek. The Buda limestone is downthrown against the Edwards limestone a short distance to the east. The limestone is exposed for about one-half mile along Bear Creek. The stone, where sampled, is free of flint, but downstream near the fault abundant flint is present. The beds range from less than a foot up to about $2\frac{1}{2}$ feet in thickness. A 1-foot bed of *Requienia* limestone is present.

The limestone varies in character from bed to bed. One bed sampled is of a grayish-cream color and is of a uniform, granular structure. Another bed is composed of a mixture of the above type material and large fossils, mostly oysters. The color of the limestone varies from light gray to light brownish gray. The first mentioned sample takes a good polish and the second takes a mirror-like polish. These limestones are classified commercially as marbles.

The limestone is composed essentially of very fine-grained calcite and contains numerous microfossils and fossil fragments. The limestone is of good quality and is attractive but is not in thick enough beds to be produced for saw blocks. It is chiefly of value for pitched face stone.

LOCALITY T–9

A deposit of Edwards limestone is located southwest of Austin, about 2 miles northwest of a railroad and about 2 miles southwest of the Austin-Fredericksburg highway. The bed sampled is a miliolid limestone which is hard, white, and only about 1 foot thick. A short distance to the south abundant *Requienia* limestones are exposed. The *Requienia* limestone outcrops on a rather gentle slope and the thickness of the beds could not be exactly determined. Individual beds may range between about 6 and 18 inches in thickness and may total about 7 or 8 feet in thickness.

The miliolid limestone is compact, slightly mottled, and of a uniform texture. The color difference is slight, ranging from light gray through very light brownish grays. Some millimeter-sized white microfossils dot the surface. The limestone takes a dull polish.

In thin section the limestone is composed predominantly of very fine-grained calcite. A small amount of calcite up to 1 mm. in grain size is present. Microfossils and fossil fragments are abundant. The bed is too thin to be used except for pitched face stone. The *Requienia* limestones of the area may be of some value.

LOCALITY T–14

A deposit of Edwards limestone is located one-fourth of a mile downstream from Oak Hill and is exposed in the bed of Williamson Creek. The nearest railroad, which is at Kouns, is about 6 miles distant. The limestone is hard, brittle, and cream-colored. About $1\frac{1}{2}$ feet of it is exposed for a distance of about 500 feet along the stream, and it dips beneath the surface in both directions along the stream. The overlying rock is a dolomite which is of little value, and the underlying rock is not exposed. The limestone has been used for terrazzo chips.

The limestone is compact, extremely fine grained, and light pinkish brown with some small elongated limonitic yellow-brown spots. A few faint manganese dioxide dendrites are present. The limestone takes an excellent polish and is classified commercially as a marble.

In thin section the limestone is composed of about 1/10 of a millimeter-sized grains of calcite in a very fine-grained groundmass of calcite. Nothing resembling fossils or fossil fragment is present. The bed is too thin to be of value except possibly for pitched face stone and terrazzo chips.

LOCALITY T–15

A deposit of Edwards limestone is located about 1.5 miles northeast of Oak Hill and about 4 miles from the railroad at Kouns. The limestone is hard, brittle, and cream-colored. It is scattered over several acres and appears to be about 1 foot thick. The limestone has been used for terrazzo chips. The limestone is compact and extremely fine grained. It is brownish gray, and the bedding direction is revealed by some variation in color. The limestone takes a good, uniform polish and is classified commercially as a marble.

It is composed of small calcite crystals in a very fine-grained groundmass of calcite. No fossils or fossil fragments are present. The limestone is too thin to be of value except possibly for pitched face stone or terrazzo chips.

LOCALITY T–16

A deposit of Edwards *Requienia* limestone is located about 3 miles northwest of the railroad at Kouns and about 100 yards north of the Austin-Fredericksburg highway. It is exposed at the head of a steep-sided draw which is tributary to Barton Creek.

This bed of stone is about 4 feet thick and has been uncovered in two places about 600 feet apart. There is about 15 feet of limestone and overburden above the *Requienia*-bearing bed. Nickell[65] reports on this stone as follows:

> *Requienia* marble outcrops on the E. C. Gaines ranch, 3½ miles southwest of Austin and one-fourth of a mile north of the Fredericksburg highway, at the head of a ravine. The ravine is 30 feet deep at its head and rapidly deepens to 150 feet toward Barton Creek. Eighteen feet below the surface is a massive limestone 15 feet thick. The *Requienia* marble forms the upper 3½ feet of this limestone, being separated from the lower part by a bedding plane which does not show plainly on the weathered surface of the ledge. Above the *Requienia* marble are several poorly defined layers of limestone of irregular texture, hardness, and thickness, separated from each other by intervals of clay several inches thick. If excavation were carried back into the ravine wall an additional 20 feet, the entire section might be composed of limestone, in layers varying from 6 to 18 inches in thickness, and of a texture and hardness suitable for use as crushed rock for highway or concrete work. Some of it may prove to be good enough for building stone. At this location the *Requienia* marble was uncovered along the bedding for 50 feet. It is hard, highly fossiliferous, and takes an excellent polish. Samples of it are numbered T-16 in The University of Texas Bureau of Engineering Research collection of building stone.
>
> The successful operation of a quarry for *Requienia* marble at this location may depend on the utilization of the overlying beds of limestone for crushed rock, to pay for the handling of the overburden. The strata are nearly horizontal, and the ground is nearly level; consequently, the thickness of overburden will not vary appreciably.
>
> The same limestone was uncovered 600 feet to the northeast of locality No. 1. The ravine at this point is 150 feet deep and would be convenient for the disposal of waste. Twelve feet or more of limestone beneath the *Requienia* marble was uncovered at this locality. More work should be done to determine the value of this apparently high quality, somewhat fossiliferous limestone. These limestone beds must extend over a wide area, as indicated by their extensive outcrop along the ravine wall. Erosion has removed soil and debris from the upper part of the ledge, exposing solid limestone from the *Requienia* marble to the surface. This supports the suggestion that solid limestone will be encountered elsewhere back from the outcrop.

The limestone is composed of abundant *Requienia* and some *Chondrodonta* in a light brownish-gray, fine-grained matrix. The fossils have mostly been replaced by calcite, some of which is clear, some milky, and the rest translucent brown. The limestone takes a good polish and is classified commercially as a marble.

Microscopically the limestone is seen to be composed of coarsely crystalline areas of calcite in a groundmass of very fine-grained calcite. The latter contains microfossils and fossil fragments. The coarsely crystalline calcite has replaced fossils.

The *Requienia* marble is of good quality, is very attractive, and should be produced as an ornamental stone. The bed is rather thin, but stone of this quality should command a premium price.

LOCALITY T-18

A deposit of Edwards limestone is located about 4 miles west of Austin, between Colorado River and Bee Caves road. It is near the head of a creek which enters Colorado River near Deep Eddy in Austin. An area of about 50 by 100 feet of limestone, somewhat jointed, is exposed in the bed of the creek. The thickness of the limestone is unknown. *Requienia* limestone beds are exposed along the hillside to the west. Other beds of limestone are numerous in this locality, and many of them have been used locally for building stone.

The limestone is of a semi-mottled appearance produced by a combination of light gray and light brownish-gray. A few fossils and fossil fragments are present. The limestone has a finely granular appearance and takes a good polish.

The limestone is composed of calcite and is crowded with microfossils which are of very fine-grained calcite and are surrounded by rather coarsely crystalline clear calcite, which makes them stand out in thin section. One large fossil in thin section is composed of very coarsely crystalline, clear calcite and the living chamber is filled with very fine-grained calcite containing some microfossils. The amount of limestone exposed is small. It is probably of value only for local use.

LOCALITY T-20

A deposit of fossiliferous Edwards limestone is located about 2½ miles northwest of the railroad at Kouns and about one-fourth of a mile north of the Austin-Fredericksburg highway. It is situated

[65]Nickell, C. O., Report on the mineral resources of Travis County, Texas: Univ. Texas, Bur. Econ. Geol., Min. Res. Sur. Circ. 39, pp. 2–3, Nov., 1941.

along the upper steep slope of Barton Creek valley and is south of the creek. A bed, about 18 inches thick, is exposed along the valley wall. A short distance above it is a *Requienia* limestone bed very similar to the one described under T–16.

The limestone is composed of abundant fossils, many of which are replaced by clear calcite. The matrix is not abundant and is mostly of two colors, one a bluish gray and the other a light brownish gray. A few of the fossils are translucent brown. A small amount of porosity is present which is largely masked by the texture of the stone. The limestone takes an excellent polish and is classified commercially as a marble.

Microscopically the limestone is composed of very fine-grained, breccia-like calcite areas surrounded by clear, coarsely crystalline calcite. One area contains radially fibrous aggregates of a brownish color which resemble serpentine. A small number of microfossils and fossil fragments are contained in the fine-grained calcite.

The limestone is thin and is located on a rather steep slope. Even though attractive in appearance, it is probably of little value.

LOCALITY T–24

A deposit of Edwards limestone is located about one-half mile west of Jollyville and just north of the road leading to Cypress Creek. The sample may have been collected just within Williamson County as the location of the county line in this area is not accurately known. The area in which the limestone is located is almost flat. A pit exposes an 18-inch bed of stone from which a sample was obtained. Some highly fossiliferous limestone ledges are present on the gentle slope between the pit and the road. Near the top of the slope is a ledge of coarsely crystalline dolomite.

The limestone is uniformly fine grained and has a slightly brownish, light gray color. It is slightly mottled, the color difference being insignificant. The limestone takes a dull polish.

The limestone was not thin sectioned, but a staining test indicates that it is predominantly composed of calcite. With a hand lens innumerable small rounded bodies can be seen which may be oolites. The limestone is not well exposed and is probably of little value as a building stone.

LOCALITY T–27B

A deposit of Edwards limestone is located one-fourth of a mile west of the upper Bull Creek road about 2 miles from the railroad at Spicewood Springs. It is situated north of Stillhouse Spring near the head of a steep-sided ravine draining northward into Bull Creek. Three beds of limestone totaling 4½ feet in thickness comprise the usable building stone at this locality. The limestone is from near the base of the Edwards limestone and contains a few flint nodules. A short distance beneath is a thick massive limestone (Comanche Peak?), somewhat nodular at the base, containing geodes of strontianite and calcite.

Nickell[66] examined this area and mentions some other localities where limestone of desirable quality is present.

The limestone is extremely fine grained and of an ivory color with some areas which are slightly tinged with yellow-brown. Clear calcite areas and gash-like veins are rather abundant. The limestone takes a good polish and commercially is classified as a marble.

The limestone was not thin sectioned. It appears to be composed essentially of calcite. The limestone is probably mostly of value for local use.

LOCALITY T–28

A deposit of Edwards limestone is located one-fourth of a mile west of the railroad at Spicewood Springs and just south of the upper Bull Creek road. The limestone bed is about 6 feet thick and contains filled burrows but otherwise is a very uniform stone. Beneath it is similar stone in thinner beds separated by zones of thin-bedded limestone. Above it is about 6 feet of honeycombed limestone which should be of value for certain decorative uses.

The limestone is more pleasing on a naturally broken surface than it is on a

[66]Nickell, C. O., *op. cit.*, pp. 5–6.

sawed surface. The sawed surface is rather a grimy, smudged, light gray with some streaked, light brown areas. A few rudistid-like fossils and other fossil fragments are present.

The limestone is composed of calcite grains mostly not more than 1/30 of a millimeter in size and some very fine-grained calcite. A few microfossils and fossil fragments are present. The limestone contains a few small areas of dolomite and does not appear to be of much value.

LOCALITY T-36

A deposit of highly fossiliferous Edwards limestone is located on the north side of Barton Creek at the top of a steep bluff about 1.5 miles upstream from Barton Springs. A power line is located about 200 yards west of the limestone deposit. Nickell (pp. 2–3) examined the limestone and removed overburden in a small area above it. He gives the following description of the beds uncovered:

	Thickness Feet	Inches
5. Overburden, thin beds of limestone and soil	3	----
4. Limestone, hard, no particular value	1	----
3. Limestone, light gray, hard, many *Turritella*	3	----
2. Sandy limestone, soft, yellow	----	4
1. Limestone, gray, fossiliferous (*Turritella*), many small cavities	6	----
Total	13	4

Bed No. 3 may prove to be of value. The middle 18 inches of No. 3 is highly fossiliferous with abundant *Turritella*-like fossils being in a horizontal position. The stone should be cut parallel to the bedding to obtain the best cross sections of the fossils. The limestone takes a good polish, which from the point of utilization classifies it as a marble. . . . Bed No. 1 contains abundant fossils and much porosity and is of value as a special decorative building stone.

Bed No. 3 is composed of long, spiral gastropods (snails) in a light buff-colored matrix. The gastropod living chambers are in part filled by the same type matrix and are in part filled by calcite crystals. Some of the gastropod shells and living chambers have been completely replaced by calcite. The calcite ranges from clear to white in color and has brilliant reflections from crystal faces, giving it a very attractive appearance. The gastropods are mostly either dark or light enough in color to contrast well with the background. A few cavities of small size, a few clear calcite veins, and a few brown limonite areas are distributed throughout. The limestone takes a very good polish and is classified commercially as a marble.

The limestone was not examined microscopically, but from a sight examination it appears to be composed chiefly of calcite.

The No. 1 bed, from a sight examination in the field, appears to be a uniform bed highly desirable for interior stone. The porosity is similar in magnitude to that found in travertines and this stone could be used as effectively as travertine.

The limestone is very beautiful and is of value as an ornamental stone. It takes a high polish and is therefore of value as a marble.

Austin Chalk

Description by Localities

Travis County

LOCALITY T-10

An Austin chalk deposit is located about 1 mile north of Manchaca Spring on the east side of Onion Creek, and a bed of chalk about 8 feet thick has been quarried for use in railroad bridge piers. It is white and contains some *Gryphaea* and oyster shells and some marcasite nodules. Drill holes in the quarry in part show enlargement due to weathering, and others apparently are unchanged. Other thick beds of chalk containing abundant *Inoceramus* fragments are present beneath the quarried bed.

The chalk is a dirty gray, chalky white color. It has almost uniform color and texture and is sprinkled with barely visible glauconite grains.

Microscopically the chalk is composed essentially of calcite and contains abundant small fragments of fossils. Many small microfossils, probably *Globigerina*, and a few green glauconite grains are present.

The Austin chalk cannot be recommended as a building stone. A quarry was opened in Val Verde County in the "Pinto limestone" (Austin chalk) to furnish stone for the Sterling Building in Houston. After only a few years of exposure, the stone is highly disintegrated and falling apart. Drill holes at the quarry, which is located in a semi-arid climate, have weathered, doubling their size. On the basis of physical tests, no responsible person would have sanctioned its use.

Serpentine

Description by Localities

Travis County

LOCALITY T–12

A deposit of serpentine and limburgite is located on Barton Creek about 1½ miles below the mouth of Little Barton Creek. Only a small amount of novelty stone, consisting of mottled serpentine, is located here. The nearest railroad point is at Kouns, a distance of about 12 miles. The limburgite dike trends N. 40° E. and is exposed in Barton Creek and again on a side branch to the southwest about 100 yards, where a test pit has been dug at the end of the dike. On the opposite wall of the test pit from the dike is a clay gouge veined with calcite, dipping 85° to the southeast. Blue clays are located to the southeast and green clays are to the northwest of the gouge, indicating the presence of a fault. The serpentine and limburgite in the creek are mostly obscured by recently deposited gravels. In one place the limestone in contact with the limburgite is somewhat hardened. The limburgite is in part amygdaloidal and has fresh olivine crystals in it.

The serpentine is grayish green and has a mottled appearance. The mottles are fragments of the original igneous rock which have been serpentinized and between which either finer grained igneous material or white calcite is located. The mottles do not take a polish, but the rest of the stone takes an excellent polish.

Microscopically the serpentine is seen to be composed of rounded aggregates of partially serpentinized trap rock surrounded by a network of coarsely crystalline calcite. The calcite is in part clouded by minute inclusions. Some calcite crystals are clouded to a definite sharp boundary and are clear elsewhere. The rounded aggregates are composed of phenocrysts in a very fine-grained unresolvable groundmass. The phenocrysts are practically entirely serpentinized, yet retain their original shape. The shape suggests that the original mineral was olivine. In some of the phenocrysts the serpentine has formed with optical continuity so that an entire phenocryst extinguishes simultaneously. Most of the phenocrysts, however, are composed of variously oriented fibrous groups.

Only a small amount of an attractive novelty stone is present. The deposit is of little, if any, value.

LOCALITY T–33

A deposit of serpentine is located at the north side of Pilot Knob and just south of an east-west road. The serpentine is exposed just east of a drain and not far below an Austin chalk cliff. The serpentine is a sedimentary deposit which accumulated at the foot of the old Pilot Knob volcano. It is composed of serpentinized fragments of igneous rock cemented by white calcite. The portion of the deposit suitable for building stone is only a few feet thick and extends for several hundred feet along the hill slope. Serpentine in this vicinity yields a coral, *Favia texana,* which indicates that the serpentine was deposited in saline waters. Its position suggests that it is of Austin chalk age.

The serpentine is composed of serpentine nodules up to one-half inch in size which are completely surrounded by white calcite. The nodules are of various shades of dark green, brownish green, and reddish green, and a few are light to dark brown. The serpentine takes a dull polish and the calcite takes a brilliant polish.

Sufficient serpentine is present to warrant a small production of it as a novelty stone.

Travertine and Onyx Marbles

Description by Localities

Gillespie County

LOCALITY G–26

A deposit of travertine is located in northeastern Gillespie County along the eastern side of Bee Rock Mountain. It is about 22 miles from Fredericksburg by road, 12 miles of which is hard surfaced. A map of the area is shown in figure 11. The travertine is honeycombed, which probably accounts for the name Bee Rock, and is mostly of a rich cream color. The deposit formed alongside a high bluff of Cap Mountain limestone and its base rests on Hickory sandstone. The travertine was deposited by a small spring-fed stream issuing from Paleozoic limestone. The deposit has a surface area of 2.5 acres and is estimated to be 100 feet thick. Using these estimates, the deposit would, therefore, contain about 11,000,000 cubic feet of travertine.

The travertine takes a high polish. The deposit contains a large amount of travertine of value as an interior decorative stone.

Llano County

Deposits of travertine are located along the east bluff of Cold Creek 1 mile north of the Valley Spring-Pontotoc road. The travertine extends as isolated deposits along the bluff for a distance of about 2500 feet. These deposits were found in February, 1943, while mapping was under way in connection with a gravity survey of the Smoothingiron granite mass.[67] Some blocks of travertine which have fallen from the sides of the vertical bluffs of the deposit are hard and ring when hit with a hammer. The amount of travertine in this area appears to be large and at least some of it is of good quality. Other travertine deposits will undoubtedly be found as the mapping of central Texas progresses.

Mason County

LOCALITY M–20

The location of and some information about an onyx marble deposit is given on page 136 in connection with sample M–21. The onyx marble is translucent, banded, and of various shades of rich brown. It takes a brilliant mirror-like polish. It appears to be composed entirely of calcite. The deposit is not of commercial importance and is mentioned merely to make known the presence of cavern deposits of onyx marble in Paleozoic rocks in the hope that commercial deposits may eventually be found.

Travis County

LOCALITY T–25

Boulders of onyx marble are scattered about the surface 6 miles north of Austin and about one-fourth of a mile north of the springs at Spicewood Springs. The main occurrence is about 150 yards south of the main road. An outcrop of the onyx marble was not located. Onyx marble is frequently found in small caverns of the Edwards limestone, but usually such deposits are small.

The onyx marble is translucent, banded, and brown, varying in intensity in different bands. The banding is wavy and rather widely spaced. A well developed transverse structure having a fros y appearance may be caused by internal reflection from calcite cleavages or crystal faces. The onyx marble takes an excellent polish. The deposit is apparently too small to be of much value.

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[67]Romberg, Frederick, and Barnes, V. E., Correlation of gravity observations with the geology of the Smoothingiron granite mass, Llano County, Texas: Geophysics, vol. 9, pp. 79-93, 1944.

PART II

Raymond F. Dawson

Physical Tests

The physical tests on selected samples of stone were made in the laboratory of the Bureau of Engineering Research by G. A. Parkinson, Assistant Testing Engineer. Some deposits of stone were not tested because there did not appear to be a sufficient quantity available to justify the time and expense of testing, while in other cases physical tests could not be made because the samples obtained were not large enough to supply the specimens. Each stone that was tested therefore represents a deposit of sufficient quantity for commercial production or of such unusual character to justify further exploration.

Compressive strength, apparent specific gravity, absorption and durability tests were made according to the methods outlined in the Bureau of Standards Technologic Paper No. 349 (1).*

Preparation of Test Specimens. Test specimens consisted of cylinders approximately 2½″ in diameter and 2¾″ high. A few of the early tests were made on 2 inch cubes but the majority of the specimens were cylindrical in shape.

A slab of stone 2¾″ thick was cut from the sample by means of a stone saw using a silicon carbide rimmed wheel. Cores were drilled from this slab on a drill press using a thin steel tubing cutter and powdered abrasive. Usually six specimens were cut from each slab, three being used for the compressive strength test and the remainder for, first, the absorption and specific gravity tests and, then, used in the durability test.

Compressive Strength. Compressive strength tests were made on dry specimens cut perpendicular to the bedding plane when such planes were discernible. After the cores were cut the ends were capped with thin beds of plaster-of-paris in order that the load might be applied uniformly over the entire surface. The diameter of each core was carefully measured in order that the cross-sectional area might be calculated. The specimens were tested in a universal testing machine between two spherical bearing blocks.

*Number refers to bibliography page 186.

Many architects and engineers believe that the compressive strength is the only criterion necessary to determine the quality of a building stone. This is not necessarily so, and opinions based solely on one test may be very misleading. Buckley (2) states,

> A high crushing strength is often taken as certain evidence of the durability of a stone, and the relative durability of different stones has often been measured by a comparison of their crushing strength. This is a gross mistake, for not infrequently a stone, having a low crushing strength, is more durable than others which are stronger.

On the other hand, Kessler and Sligh (1) express the following opinion:

> Compressive strength is mainly of interest in comparing the qualities of different materials, although it is also of interest in a structural sense. It is frequently pointed out that practically all natural stone is strong enough for any structural requirement. However, there are many uncertainties as to the stress in masonry walls. It is not unusal to see broken stones in the walls of modern structures. Conditions which may cause breakage are numerous, but probably the most common are as follows: Unequal settlement, improperly bedded joints, unequal expansion of steel or concrete frames and the stone facing, and swaying of tall buildings due to earth tremors, wind storms, blasting, etc. Experience has taught that a large factor of safety is necessary to guard against cracking or spalling of the stone under such conditions. Probably the best illustration that can be offered in support of the above statement is that of the Washington Monument in Washington, D.C. In the highest stressed part of the masonry the factor of safety is nearly 20, yet the marble shows many cracks. Some of these are apparently due to unequal distribution of the load on certain blocks or a concentration of load on the pointing mortar, while others resemble compression failures.
>
> High strength is always a desirable characteristic aside from its advantage in better resisting the usual stresses. In general, high strength denotes durability. A strong material is less apt to become defaced in those parts of the structure which are subject to accidental injury. All arrises that are within the reach of human hands are apt to become chipped, and thus badly marred in appearance. Weak stone is readily defaced in this way and often suffers defacement during

construction. Delicate carvings in order to withstand accidental injury require considerable strength in the stone.

In modern construction the maximum load carried by the stone is rarely over a few hundred pounds per square inch and often much less. Therefore, the weakest stones will usually have adequate compressive strength to resist the loads which may be imposed upon them. The writer agrees with Kessler and Sligh that there are many places where high strength stone is desirable and worth the additional cost necessary to work the stone. This is especially true in locations where the surface or carving is likely to become defaced. However, he cannot agree that the stone should be required to make up for the shortcomings of the foundation engineer or craftsman who sets the stone. As for unequal expansion between the frame and stone facing and the swaying of the building, it is conceivable that the soft, more resilient stone might crack less than a brittle, hard one.

There are large quantities of dense, hard stone available in Texas and there is no excuse for permitting the use of soft stone in those places where hard stones are necessary. The results of the compressive strength tests are given in Tables No. 51 and 52. It will be observed that both the gray and pink granites have high compressive strengths ranging from 16,500 pounds per square inch to 37,800 pounds per square inch. This represents a factor of safety against crushing of at least from 3,300 to 7,500 per cent for heavy wall loads. The strongest granite would support a wall 6¼ miles high before it would crush under its own weight. Practically all of the marbles have relative high compressive strengths and many of them are equal to the granites in this respect. The sandstones also have a relative high resistance to crushing but in general are not as strong as the granites and at least half of the sandstones tested indicated strengths below that shown by most of the marbles.

As might be expected, the limestones had the lowest average compressive strength. However, one limestone had a compressive strength of 20,666 pounds per square inch which was greater than several of the granites. The lowest limestone only withstood a load of 1,723 pounds per square inch before it failed but even then it had a factor of safety of almost 350 per cent for very heavy loading, and probably 2 to 3 times this value for ordinary construction. This weakest stone would support a wall 0.4 of a mile high, or almost 4 times as high as the San Jacinto Monument, before it would fail due to its own weight.

Absorption Test. The cylinders were dried to constant weight in an electric oven at 105° C., cooled in a desiccator, and weighed to the nearest 0.1 gram. The specimens were immersed in water at room temperature for a period of two weeks and then weighed again after the surface moisture had been removed with a towel.

The per cent absorption was determined in the following manner:

$$\%\ \text{absorption} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

From Tables No. 51 and No. 52 it will be found that there is a wide range in the absorption of Texas stones, the lowest being 0.03% while the highest is 15.07%.

Absorption is related to the porosity of the stone and has been considered a measure of the stone's resistance to deterioration due to freezing and thawing. However, it is not the amount of pore space in a stone but the size and shape of the pores that determine its ability to resist freezing stresses. Buckley (2) states,

> It should be kept in mind, in this connection, that a fine and coarse grained rock, in one of which the interstices are very minute and in the other of which they are much larger, may have the capacity to absorb equal amounts of water. Of two equally saturated rocks, one with 10 per cent. and the other with 3 per cent. of pore space, in which the pores are of equal size, the former will be in the greater danger of freezing. The percentage of the pore space that is filled with water will also condition the results of freezing. If two-thirds of a rock is saturated more injury will result from its freezing than if only one-third were saturated. If none of the pores are more than 9–10 filled with water, the effect of freezing will be nothing, because the increased bulk will no more than fill the spaces between the grains.
>
> The amount of water contained in the pores at a given time depends, of course, upon the amount of water initially absorbed, the time that has elapsed since absorption, the condition of the atmosphere, and the size of the pores. In the walls of a building it is only in exceptional cases that the stone is saturated, but when it is, the

water of saturation is, as a rule, quickly removed, except in the lower courses below the water line, provided the pores are of greater than sub-capillary size. It would appear from the above, that the most important factor in estimating the danger from freezing and thawing, is the rapidity with which the rock gives up its included water, which depends, as stated above, mainly on the size of the pore spaces. The second factor of importance is the amount of water contained in each of the pores at the time of freezing. Third and last in importance is the total amount of pore space. The higher the percentage of pore space, provided the pores are of the same size and the degree of saturation be equal, the greater the danger from freezing.

T. S. Hunt, in *Chemical and Geological Essays*, says: "Other things being equal, it may properly be said that the value of a stone for building purposes is inversely as its porosity or absorbing power." This statement has been quoted by various authorities among whom may be mentioned T. C. Hopkins, who says, in his report on the Pennsylvania Brownstone: "Other things being equal, the more porous the stone the greater the danger from frost." Following these and other writers the mistake has often been made of estimating the danger, from freezing, by the capacity which a stone has to absorb water. Likewise the capacities which two stones have to withstand weathering are constantly being compared from the standpoint of their ratios of absorption. Such estimates and comparisons are very misleading, for one should not only know the capacity which a stone has to absorb water, but he should, above all, know the size of the pores. As shown above, the latter factor is of much greater importance than the former.

In an earlier series of tests, conducted by the Bureau of Engineering Research, an attempt was made to determine durability by the sodium sulphate soundness test. Although it is realized that this test has severe limitations and may give misleading results, the following observation is not dependent on the test results. In making the sodium sulphate test, stone specimens are soaked in a solution of sodium sulphate for a specified period of time followed by drying in an oven at constant temperature. The idea being that the stone would absorb the solution during the soaking period and during drying, the sodium sulphate crystals that were formed would exert stresses on the specimen similar to the ice crystals during freezing. One sample that was tested had a very high absorption indicating a large amount of pore space. But, evidently, these pores were very large and went straight into the stone because, on drying, the sodium sulphate crystals formed and pushed out of the stone, sometimes protruding as much as ¼ inch beyond the surface, leaving the stone undamaged. There is no reason why ice crystals should not do the same thing.

Under the discussion of the durability test, it will be shown that only a few cycles of freezing and thawing occur each year that are likely to be detrimental to building stone. This will not be true in the case of a highly absorptive stone in contact with the ground or other sources of free moisture. Highly porous stones will have a high rate of absorption of capillary water; therefore, if water is available, these stones will be kept saturated and each cycle of freezing will be a destructive one. Thus, one year of a highly absorptive stone in this position would be equivalent to ten to twenty-five years deterioration under more favorable conditions. For this reason, highly porous stones should never be placed in contact with the ground or other sources of continuous free moisture.

In the warm, humid atmosphere of the southern coastal states, many stones are discolored by organic plants which grow on the surface of the stone. These fungi are probably species of lichens and algae and give the stone a black color. The lichen is peculiar in that it can live for a long period of time without moisture. However, it grows only when sufficient moisture is available. These fungi will live on the dense hard stones but, because of the lack of moisture, grow very slowly and generally cause only little discoloration. However, in the case of the more porous, highly absorptive stones, comparatively large quantities of water are held by the stone which are available to the plants over a considerable period of time, thus promoting prolific growth. The greatest discoloration will occur on coping stones and projecting ledges where water can collect and penetrate the stone, and also in streaks down the sides of buildings where leaky downspoutings, cracked cornices or copings permit excess water to come in contact with the walls.

While the presence of lichens often adds to the charm of an old building, a black streak down the wall near a drain pipe or even a discolored coping stone contributes little to a structure's beauty. In cases where highly absorptive stones are used in exterior walls, they should be protected from excessive moisture and coping stones treated with a colorless, waterproofing material.

Apparent Specific Gravity. The apparent specific gravity of a material is the ratio of the dry weight of the material to the weight of an equal volume of some other material which is taken as a standard of comparison. Usually, water is taken as the standard of comparison for solids and it was used in these tests. The volume of each specimen was determined by weighing it, first dry in air and then submerged in water; the difference in weight being the weight of the volume of water displaced or the weight of a volume of water equal to the volume of the specimen. During the weighing of the submerged specimen the stone will absorb moisture almost in proportion to its porosity; therefore, accurate results could not be obtained by weighing specimens submerged dry. To prevent the absorption of water during the submerged weighing, the cylinders were not weighed in this condition until they were completely saturated during the absorption test. The apparent specific gravity was calculated by the following formula:

$$G = \frac{W_1}{W_2 - W_3}$$

where

G = apparent specific gravity
W_1 = dry weight of the specimen
W_2 = wet weight of the specimen
W_3 = submerged weight of the specimen

The apparent specific gravity is useful in determining the unit weight of a material. The dry weight in pounds per cubic foot of a stone may be determined by multiplying its apparent specific gravity by 62.5.

Durability Test. In reality, durability tests should include all the various factors that affect the life of a building stone, but, inasmuch as deterioration is primarily the result of freezing action on the stone, that is the only test included under this heading. Perhaps the title of the section should be "weathering qualities" but it is felt that if a competent designer knows the weathering resistance of the available stones, he can select the proper one by studying the local conditions and the physical characteristics of the stone. Certainly, no engineer or architect would think of using a soft stone in the floors or steps of a public building where the abrasive action of many feet would soon wear the stone away. It has been recommended repeatedly, (see (2), (3), (4) and (5)) that stones which show any stratification or schistosity should not be laid on edge but always on the natural bed. To place such stones on edge promotes exfoliation and scaling of the surface.

In industrial areas and cities where large quantities of coal are burned, the atmosphere will be polluted with acid gases which will attack certain building stones. Since the gases will disintegrate calcium carbonate, they may cause rapid deterioration of limestones and sandstones which contain a calcium carbonate binder. One would expect that these gases would cause greater disintegration of the softer, more porous stones than dense ones of the same chemical composition.

The main factor contributing to the deterioration of stone exposed to weather, is the internal stresses caused by freezing. When a saturated stone is cooled below 32° F., the water in the pores freezes and expands since water increases in volume on freezing. The expansion of this pore water creates the internal stresses that may cause the structure of the stone to break down, especially after several repetitions of the stress. Buckley (2) states:

> The expansive force of freezing water is graphically described by Geikie as being equal to the weight of a column of ice a mile high, or a little less than 150 tons to the square foot. One centimeter of water at 0° C. occupies 1.0908 cm. in the form of ice at 0° C. It is this expansion of about one-tenth that does the damage when confined water solidifies.

From the above statement one might expect that unless it possessed a strength greater than 2,000 pounds per square inch, any stone would be completely disintegrated after being frozen. However, this is not true since there are several factors which influence the effect of freezing on rocks. In the discussion of the absorption test, it was pointed out that the shape of the pores in the stone has a decided influence on the effect of freezing and, in some cases, stones with large pore spaces were more resistant to freezing action than others with small percentage of pore-spaces.

Unless the pores of the stone are completely filled with water, freezing has little effect on it. When water in partially filled pores freezes, it expands in the pores and exerts no stress on the stone. Buckley (2) again states:

> If none of the pores are more than 9–10 filled with water, the effect of freezing will be nothing because the increased bulk will no more than fill the spaces between the grains.

Therefore it is apparent that all freezing is not detrimental to the stone in building walls. In fact, in Texas climate, there will be only an occasional freezing of the stone in a saturated condition unless the moisture comes from some source other than rainfall or melting snow. Kessler and Sligh (1) make the following observations:

> Probably the worst condition in buildings occurs when snow is lying on the coping, cornice, etc., and this thaws slightly in the middle of the day, which keeps those parts of the masonry fairly well soaked until freezing temperatures are again reached. Also, the lower courses of masonry are kept in a damp condition due to moisture rising through the stone by capillarity. Other parts of the buildings are less subject to soaking. . . .
>
> The temperature and precipitation records for three winters at Washington were examined. It was assumed that temperatures 2° below the freezing point or lower would congeal the moisture in the stone. The number of times the temperature fell below this point after thawing weather were counted. Unless precipitation had occurred within 24 hours previous to such temperature drops they were not counted, since it is probable that the stone would be too dry to be injured. The average number of freezing spells so counted for the three winters was 16. This may be near enough to the average climatic conditions for estimating purposes. If each freezing were as severe as the test conditions, one could estimate with some degree of accuracy how long the various materials would last in this climate, but evidently stone in a building has more time to dry before freezing occurs than the test specimens have. It would probably be fair to assume that one-fourth of this number are severe; that is, one year of actual weathering is equivalent to four freezings under the test conditions. On such basis the least resistant materials, which were disintegrated in 100 freezings, would give 25 years' service, and those that withstood 1,000 freezings would be good for 250 years.

In most localities in Texas the weathering conditions would not be so severe as those in Washington, D.C.

The freezing tests were made upon the same specimens that had been used in the absorption and apparent specific gravity test. Since the cores had soaked for two weeks during the absorption test, they were saturated at the start of the freezing test. The specimens were placed in flat pans which were filled with water to a depth equal to about one-third the height of the cores. The pans containing the stones and water were placed in the freezing unit which was held at 0° F., and permitted to remain there until they were completely frozen. The pans of stone and ice were removed from the freezing unit and immersed in a tank of water at room temperature for a period of one hour during which time they were completely thawed. This procedure constituted one cycle of the freezing test. During a normal work day two cycles of the test could be completed by running one of the freezing periods during the night. The freezing unit consisted of a four-compartment ice-cream cabinet with an extra large compressor and special controls.

From time to time each specimen was carefully examined and classified as to its condition. The specimens were classified in the same manner that was used by Kessler and Sligh (1), namely, by means of the groupings shown in figure 18 (reproduced by permission of the National Bureau of Standards). In this grouping "a" condition showed no effect of the freezing while "b" condition showed only a slight effect. Each stage showed progressively greater deterioration until "h" condition was reached which was considered a complete failure. On reaching this condition the test was discontinued. Because of the time involved, it was impossible to carry all the samples to complete failure or even partial failure in some cases. Therefore, it was decided to discontinue the freezing tests after 400 cycles which according to Kessler and Sligh (1) is equivalent to 100 years of weathering in a climate similar to that of Washington, D.C. Several of the samples were carried beyond the 400 cycles when space in the freezing unit permitted.

The results of the freezing tests are given in Tables No. 51 and No. 52. The values are average conditions for the three specimens and in cases where one core was considerably worse or better than the others it was not included in the average but a notation relative to its condition was made under "Remarks." Not all of the specimens failed by disintegrating in the manner shown in figure 18. In fact, many of them failed by splitting along seams or joints. Some split in a vertical or diagonal direction but the majority separated in a horizontal plane producing discs of varying thickness. Stones failing in this manner were classified in the same order and by the same letter used in figure 18.

An examination of Table No. 51 will show that the freezing test had little effect on the granites as most of them were classed "a" after the test was completed and none were classed lower than "b." The pre-Cambrian marbles also withstood this test remarkably well and only one of this group showed serious disintegration and this may have been due to a poor sample. There was considerable variation in the durability of the sandstones as some withstood the test fairly well while others failed badly.

The calcite and dolomite marbles of the Cambrian and Ordovician groups generally withstood the freezing test very well, while the Mississippian and Marble Falls stones were not so good, although at least one Marble Falls stone (Bu–14) resisted freezing very well.

With two exceptions the limestones deteriorated rather rapidly under this test. It is of interest to note that one of these exceptions is a Cedar Park limestone which is usually considered a soft stone. Two other Cedar Park limestones that failed rather quickly (condition "h" in slightly more than 100 cycles) have been used extensively for building purposes throughout Texas and have resisted weathering in general quite well. This leads one to believe that our freezing test was actually more severe than was anticipated or that the climatic conditions of the

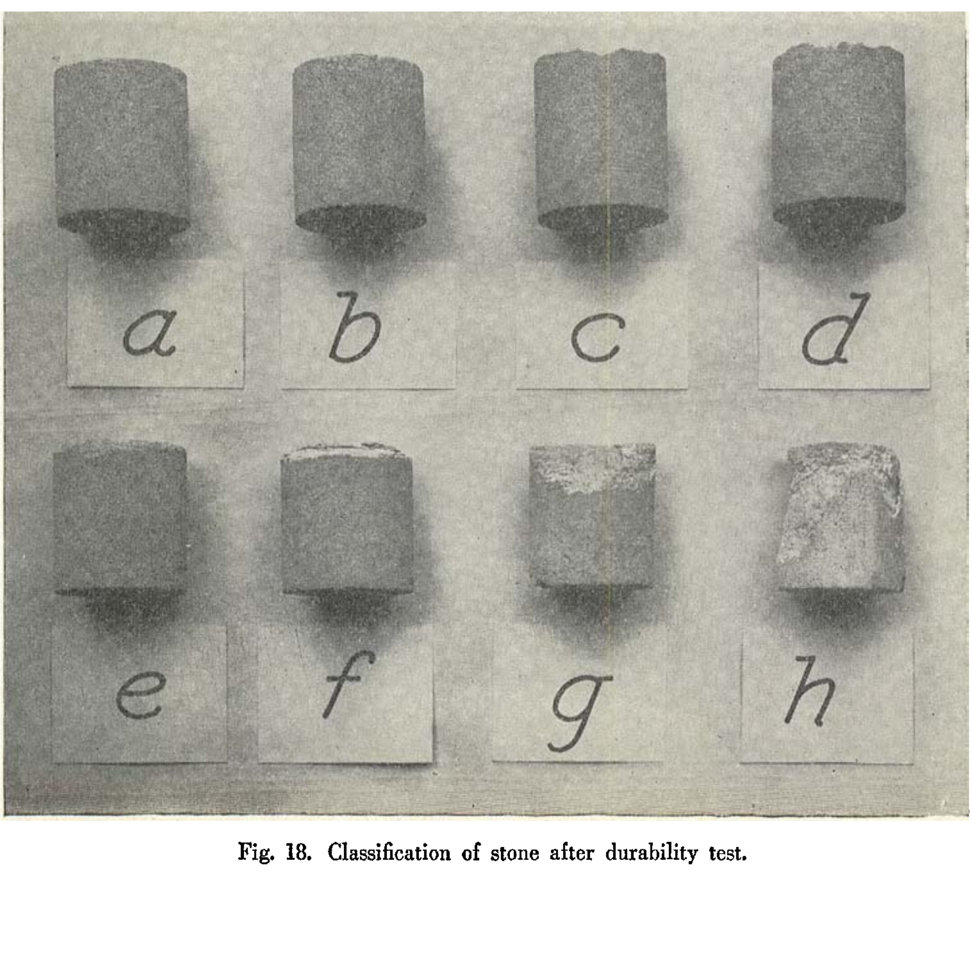

Fig. 18. Classification of stone after durability test.

southwest are not nearly so bad as those of Washington, D.C. The old library building at The University of Texas was constructed of one of these stones and has withstood 33 years of actual weathering with but very little deterioration.

After the freezing tests were completed it was decided to test in compression all the specimens which were not seriously damaged to determine the amount of deterioration in the strength of stones during the 400 (and over) cycles of freezing and thawing. These results are shown in Table No. 53.

The freezing test caused an average reduction in strength of approximately 15 per cent for both the pink and gray granites. The pre-Cambrian marbles (both calcite and dolomite) lost less than 10 per cent of their original strength while the Cambrian marbles (both calcite and dolomite) lost more than 18 per cent of their original strength. In the other groups the number of samples tested were so small that it is impossible to draw any definite conclusion, but it appears that all the limestones that withstood the freezing tests lost very little of their compressive strength.

The individual specimens gave results almost as uniform after being through the freezing test as were obtained on the unfrozen cores. In both cases only a few specimens showed a variation greater than 10 per cent of the average of the group. The compressive strength determinations on the samples that had been through the freezing test were made approximately one year la'er than the original compression tests. The strength of some stones increases with age, and this is especially true with the limestones, it may account for the indicated small loss in compressive strength of these samples.

Conclusion. This investiga'ion shows that Central Texas contains an unlimited supply of excellent building stone that ultimately should be utilized in one of the major industries of the region. No other known area of comparable size contains so great a variety of colors and textures in its stone deposits. Granites, marbles and serpentines of almost every known color and texture have been located as well as a smaller number of excellent sandstones, limestones and soapstones.

As might be expected, these tests show that in general, the granites offer the greatest resistance to weathering and have higher crushing strength than the other types of stone that were tested. Since granite is a very hard stone the cost of quarrying and processing must necessarily be very high, thus making the stone expensive to use. But in building stone as in most other commodities, one must pay more to get the best. The majority of Texas granites are of superior quality and equal to the best stones found anywhere. It is true that a small amount of granite found in Texas is of inferior quality but such deposits are unconditionally condemned.

Two deposits of granite contain iron of such a nature that on weathering the stone stains badly from this source. Certain promoters have condemned all Texas granites because of these stones, stating that they all contain too much iron and intimating that all would stain for this reason. This is not true, because the amount of staining depends upon the type of iron present and not upon the quantity. Bowles (6) comments as follows:

> The chemical composition of granite has little economic significance. Many prospective granite-quarry operators wish to have samples of their rock analyzed to determine its quality and probable value, failing to realize that any one element or compound may form constituent parts of several different minerals, some of which may be desirable and some undesirable. For example, an analysis may show a certain amount of iron, but without a very complete analysis and careful calculation the amount of iron present as a constituent of a stable biotite or hornblende or of an unstable and detrimental pyrite or garnet can not be determined. A chemical analysis, however, may indicate the general composition; thus a high silica content would indicate a high percentage of free quartz. Analysis of a granite is therefore much less important than determining its mineralogical composition.

It will also be observed that there is an abundance of high-strength durable marbles in Texas both in the pre-Cambrian and the Cambrian and Ordovician groups and that there is no excuse for the production of inferior marbles in the State.

While the number of sandstone deposits found in the area is limited, at least two are of high quality that should produce excellent building stones.

This investigation discloses that the Glen Rose limestone and Austin chalk do not resist the freezing test and these stones should not be used exposed to weather without a careful investigation of the deposit in this regard. While some of the Cedar Park and Edwards limestones were highly resistant to the freezing test others were inferior; therefore, these groups should also be thoroughly tested before being placed on the market.

It may be concluded that freezing under adverse conditions will likely cause a reduction in the compressive strength of the stone but if it does not disintegrate, the loss in strength will not be sufficient to cause trouble.

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Table 51. Physical properties of central Texas building stones arranged by geological formations.

No.	Comp. Str.	Sp. Gr.	% Absorp.	Durability test, cycles for condition a	b	c	d	e	f	g	h	Remarks
			GRAY GRANITE									
Bu-17	23,030	2.71	0.15	400								
G-12	17,800	2.728	0.15	263	400							1 core condition "c"
Ll-21	35,417	2.62	0.18	406								
Ll-24	28,900	2.63	0.17	400	450							
Ll-25	28,850	2.642	0.16	488								
Ll-26	26,350	2.655	0.15	500								
Ll-37	27,565	2.645	0.21	400								
Ll-39	33,767	2.64	0.23	426								
Ll-52	28,900	2.621	0.25	400								
M-23	30,300	2.62	0.28	400								
			PINK GRANITE									
Bl-1	22,540	2.613	0.20	500								1 core condition "b"
Bl-7	23,150	2.609	0.30	400	500							1 core condition "c"
Bl-8	25,867	2.64	0.27	400								
Bu-5	20,350	2.648	0.15	470								1 core condition "b"
G-11	33,300	2.634	0.70	470								
Ll-13	19,600	2.623	0.19	500								
Ll-28	16,500	2.634	0.22	488								1 core condition "b"
Ll-30	17,450	2.672	0.21	488								
Ll-31	27,600	2.620	0.22	500								
Ll-35	37,800	2.650	0.10									No freezing test made
Ll-41	30,180	2.63	0.21	400								
Ll-45	25,517	2.65	0.26	400								
Ll-63	21,400	2.641	0.15	488								1 core condition "b"
M-7	19,183	2.643	0.23	400								
M-9	19,350	2.64	0.30	95	550							
M-11	17,525	2.632	0.22	329	400							
M-16	23,580	2.680	0.21	400								
M-17	27,717	2.628	0.30	400								
			PRE-CAMBRIAN CALCITE MARBLE									
Ll-1	15,600	2.755	0.03	476								
Ll-5	18,970	2.780	0.06	263	400							1 core condition "c"
Ll-27	16,450	2.746	0.13	202	406							1 core condition "c"
Ll-42	11,700	2.762	0.5	400	476							
Ll-53	14,735	2.755	0.06	400								
Ll-58	14,800	2.759	0.05	406								1 core opened on seam at 234 cycles
Ll-59	20,150	2.669	0.06	406								1 core opened on seam at 234 cycles
M-10	18,917	2.680	0.78	48	263	400						1 core condition "d"

Table 51. (Continued.)

No.	Comp. Str.	Sp. Gr.	% Absorp.	Durability test, cycles for condition a	b	c	d	e	f	g	h	Remarks
PRE-CAMBRIAN DOLOMITE MARBLE												
Bu–10	19,500	2.827	0.10	438								
Ll–6	21,100	2.878	0.05	464								
Ll–6A	22,395	2.877	0.05	464								
Ll–34	19,580	2.803	0.08	476								
Ll–54	19,700	2.790	0.249	57	131	277	339	400				
Ll–55	21,067	2.912	0.09	263	400							1 core condition "d"
SOAPSTONE												
G–6	3,723	2.811	0.35	400								
SANDSTONE												
Bl–13	14,267	2.376	3.62	92		176		250	440			
Bu–43	12,217	2.199	6.05	311		402						1 core condition "b"
Bu–2	19,713	2.441	1.96	187	244	400						
Mills–1	8,500	2.198	6.69		17		26		34		69	
S–2	5,840	2.098	8.66			21			73		104	
S–21	7,070	2.104	7.80			82		147			206	
CAP MOUNTAIN MARBLE												
Bl–12	27,917	2.686	0.33	252	440							
Bu–22	21,560	2.738	0.24	277	328		350		377	400		
Bu–26	16,650	2.686	0.40	277	400							
WILBERNS MARBLE												
Bu–21	28,575	2.722	1.01		48		189	263	400			
G–19	8,048	2.672	0.78		48		263	400				
Ll–60	21,650	2.632	1.13	178				191			229	Split on seams started at 191 cycles
CAMBRIAN and ORDOVICIAN CALCITE MARBLE												
Bu–11	23,067	2.712	0.10	263	410							
Bu–16	22,720	2.726	0.071	277	339	400						
Bu–31	19,230	2.707	0.15		223	400						
Bu–38	18,800	2.702	0.14	218	400							1 core condition "a"
Bu–42	18,450	2.710	0.19	223	400							1 core condition "c"
Ll–47	16,500	2.714	0.076		139	277		400				
S–18	22,300	2.707	0.15		230			440				
CAMBRIAN and ORDOVICIAN DOLOMITE MARBLE												
Bl–2	28,867	2.752	0.67	400	470							
Bl–18	29,965	2.776	0.59	227	400							
Bu–4	36,150	2.782	0.45	218		400						1 core condition "b"
Bu–34	33,735	2.736	0.80	220	377	488						Side of core split off at 225 cycles
Bu–35	27,000	2.819	0.13	377	470							
Bu–36	25,467	2.811	0.13	250	450							1 core condition "c"
S–6	21,033	2.702	0.22		48	263	400					
MISSISSIPPIAN MARBLE												
M–22	9,540	2.560	0.96	47		150		238	440			
MARBLE FALLS LIMESTONE and MARBLE												
Bu–14	32,997	2.636	0.54	187	383	476						Small cracks developed
S–7	16,400	2.567	1.61		18		48		87		123	
S–9	25,983	2.333	3.79		44		76			193	227	
S–16	10,688	1.860	13.35								70	
GLEN ROSE LIMESTONE												
T–27a	4,790	1.988	15.07						4	5	36	
T–32	3,267	1.996	12.38							11	13	
CEDAR PARK LIMESTONE												
T–2	3,680	2.083	10.49					6			15	
T–30	11,595	2.432	3.16								20	
T–34	10,825	2.471	2.65	223	400							1 core condition "a"
T–37c	2,423	1.953	9.39		16					38	108	Cream limestone
T–37s	1,723	1.937	8.95			38		75			125	Shell limestone
EDWARDS LIMESTONE												
T–4	20,666	2.536	2.55	400								1 core condition "b"
T–28	6,357	2.140	8.43							35	47	
AUSTIN CHALK												
T–10	2,775	1.962	11.61			6					50	

Table 52. Physical properties of central Texas building stones arranged by counties.

No.	Comp. Str.	Sp. Gr.	% Absorp.	Durability test, cycles for condition a	b	c	d	e	f	g	h	Remarks
BLANCO COUNTY												
Bl–1	22,540	2.613	0.20	500								1 core condition "b"
Bl–2	28,867	2.752	0.67	400	470							
Bl–7	23,150	2.609	0.30	400	500							1 core condition "c"
Bl–8	25,867	2.64	0.27	400								
Bl–12	27,917	2.686	0.33	252	440							
Bl–13	14,267	2.376	3.62	92		176		250	440			
Bl–18	29,965	2.776	0.59	227	400							
BURNET COUNTY												
Bu–2	19,713	2.441	1.96		244	400						
Bu–4	36,150	2.782	0.45	218		400						1 core condition "b"
Bu–5	20,350	2.648	0.15	470								1 core condition "b"
Bu–10	19,500	2.827	0.10	438								
Bu–11	23,067	2.712	0.10	263	410							
Bu–14	32,997	2.636	0.54	187	383	476						Small cracks developed
Bu–16	22,720	2.726	0.07	277	339	400						
Bu–17	23,030	2.71	0.15	400								
Bu–21	28,575	2.722	1.01		48		189	263	400			
Bu–22	21,560	2.738	0.24		328		350		377	406		
Bu–26	16,650	2.686	0.40	277	400							
Bu–31	19,230	2.707	0.15		223	400						
Bu–34	33,735	2.736	0.80	220	377	488						Side of 1 core split off at 225 cycles
Bu–35	27,000	2.819	0.13	377	470							
Bu–36	25,467	2.811	0.13	250	450							1 core condition "c"
Bu–38	18,800	2.702	0.14	218	400							1 core condition "a"
Bu–42	18,450	2.710	0.19	223	400							1 core condition "c"
Bu–43	12,217	2.199	6.05	311		402						1 core condition "b"
GILLESPIE COUNTY												
G–6	3,723	2.811	0.35	400								
G–11	33,300	2.634	0.7	470								
G–12	17,800	2.728	0.15	263	400							1 core condition "c"
G–19	8,048	2.672	0.78		48		263	400				
LLANO COUNTY												
Ll–1	15,600	2.754	0.03	476								
Ll–5	18,970	2.780	0.06	263	400							1 core condition "c"
Ll–6	21,100	2.878	0.05	464								
Ll–6A	22,395	2.877	0.05	464								
Ll–13	19,600	2.623	0.19	500								
Ll–21	35,417	2.62	0.18	406								
Ll–24	28,900	2.631	0.17	400	450							
Ll–25	28,850	2.642	0.16	488								
Ll–26	26,350	2.655	0.15	500								
Ll–27	16,450	2.746	0.13	202	406							1 core condition "c"
Ll–28	16,500	2.634	0.22	488								1 core condition "b"
Ll–30	17,450	2.672	0.21	488								
Ll–31	27,600	2.620	0.22	500								
Ll–34	19,580	2.803	0.08	476								
Ll–35	37,800	2.650	0.10									No freezing test made
Ll–37	27,565	2.645	0.21	400								
Ll–39	33,767	2.64	0.23	426								
Ll–41	30,180	2.63	0.21	400								
Ll–42	11,700	2.762	0.5	400	476							
Ll–45	25,517	2.65	0.26	400								
Ll–47	16,500	2.714	0.07		139	277		400				
Ll–52	28,900	2.621	0.25	400								
Ll–53	14,735	2.755	0.06	400								
Ll–54	19,700	2.790	0.25	57	131	277	339	400				
Ll–55	21,067	2.912	0.09	263	400							1 core condition "d"
Ll–58	14,800	2.759	0.05	406								1 core opened on seam at 234 cycles
Ll–59	20,150	2.669	0.06	406								1 core opened on seam at 234 cycles
Ll–60	21,650	2.632	1.13	178				191			229	Split on seams
Ll–63	21,400	2.641	0.15	488								1 core condition "b"

Table 52. (Continued.)

No.	Comp. Str.	Sp. Gr.	% Absorp.	Durability test, cycles for condition a	b	c	d	e	f	g	h	Remarks
				MASON COUNTY								
M-7	19,183	2.643	0.23	400								
M-9	19,350	2.64	0.30	95	550							
M-10	18,917	2.680	0.78	48	263	400						1 core condition "d"
M-11	17,525	2.632	0.22	329	400							
M-16	23,580	2.680	0.21	400								
M-17	27,717	2.628	0.30	400								
M-22	9,540	2.560	0.96	47		150		238	440			
M-23	30,300	2.62	0.28	400								
				MILLS COUNTY								
Mills-1	8,500	2.198	6.69		17		26		34		69	
				SAN SABA COUNTY								
S-2	5,840	2.098	8.66			21			73		104	
S-6	21,033	2.702	0.22		48	263	400					
S-7	16,400	2.567	1.61		18		48		87		123	
S-9	25,983	2.333	3.79		44		76			193	227	
S-16	10,688	1.860	13.35								70	
S-18	22,300	2.707	0.15		230			440				
S-21	7,070	2.104	7.80			82		147			206	
				TRAVIS COUNTY								
T-2	3,680	2.083	10.49					6			15	
T-4	20,666	2.536	2.55	400								1 core condition "b"
T-10	2,775	1.962	11.61			6					50	
T-27a	4,790	1.988	15.07						4	5	36	
T-28	6,357	2.140	8.43							35	47	
T-30	11,595	2.432	3.16								20	
T-32	3,267	1.996	12.38							11	13	
T-34	10,825	2.471	2.65	223	400							1 core condition "a"
T.Q-CC	2,423	1.953	9.39		16					38	108	
T.Q-Shell	1,723	1.937	8.95			38		75			125	

Table 53. Effect of freezing on the compressive strength. Value given in pounds per square inch.

No. of Sample	Comp. Str. Before Freezing	Comp. Str. After Freezing	% of Str. Before Freezing
Gray Granite			
Bu-17	18,300	20,367	111.2
G-12	17,800	14,250	80.1
Ll-21	35,417	34,575	97.6
Ll-24	28,900	19,567	67.7
Ll-25	28,850	23,300	80.6
Ll-26	26,350	22,450	85.2
Ll-37	27,560	21,933	79.6
Ll-39	33,767	28,900	95.6
Ll-52	28,900	24,033	83.2
M-23	30,300	26,400	87.1
Average			86.8
Pink Granite			
Bl-1	22,540	20,175	89.4
Bl-7	23,150	15,102	65.3
Bl-8	25,867	21,600	83.6
G-11	33,300	26,500	79.6
Ll-13	19,600	19,485	99.4
Ll-28	16,500	14,980	90.4
Ll-31	27,600	22,983	83.2
Ll-41	30,180	27,783	92.1
Ll-45	25,517	20,473	80.2
M-7	19,183	17,667	92.2
M-11	17,525	14,675	83.6
M-16	23,580	22,605	96.0
M-17	27,717	20,890	75.3
G-13	21,400	17,367	81.2
Average			85.1

Table 53. (Continued.)

No. of Sample	Comp. Str. Before Freezing	Comp. Str. After Freezing	% of Str. Before Freezing
Pre-Cambrian Calcite Marble			
Ll-1	15,600	15,019	96.3
Ll-5	18,970	19,058	100.5
Ll-27	16,450	13,435	81.6
Ll-42	11,700	11,317	96.7
Ll-53	14,735	15,817	107.4
Ll-58	14,800	15,800	106.7
Ll-59	20,150	16,950	84.2
M-10	18,917	13,111	69.3
Average			92.8
Pre-Cambrian Dolomite Marble			
Bu-10	19,500	18,000	92.4
Ll-6	21,100	19,692	93.3
Ll-34	19,580	18,733	95.6
Ll-54	19,700	22,975	116.5
Ll-55	21,067	17,800	84.6
Ll-6A	22,395	22,467	100.3
Average			97.1
Soapstone			
G-6	3,723	3,210	86.2
Sandstone			
Bu-43	12,217	11,550	94.6
Bu-2	19,713	17,325	87.8
Average			91.2

Table 53. (Continued.)

No. of Sample	Comp. Str. Before Freezing	Comp. Str. After Freezing	% of Str. Before Freezing
	Cap Mountain Marble		
Bl–12	27,917	19,000	68.0
Bu–26	16,650	16,612	99.8
Average			83.9
	Cambrian and Ordovician Calcite Marble		
Bu–11	23,067	16,483	71.5
Bu–16	22,720	15,333	67.4
Bu–31	19,230	20,108	104.9
Bu–38	18,800	19,533	103.8
Bu–42	18,450	17,017	92.2
Ll–47	16,500	11,952	72.5
S–18	22,300	14,825	66.4
Average			82.7

Table 53. (Continued.)

No. of Sample	Comp. Str. Before Freezing	Comp. Str. After Freezing	% of Str. Before Freezing
	Cambrian and Ordovician Dolomite Marble		
Bl–2	28,867	20,600	71.4
Bl–18	29,965	20,687	69.0
Bu–4	36,150	32,617	90.3
Bu–34	33,735	27,700	82.1
Bu–35	27,000	23,800	88.2
Bu–36	25,467	21,717	85.4
S–6	21,033	18,808	89.4
Average			82.3
	Marble Falls Limestone		
Bu–14	32,997	29,600	89.7
	Cedar Park Limestone		
T–34	10,825	10,350	95.6
	Edwards Limestone		
T–4	20,666	18,283	98.5

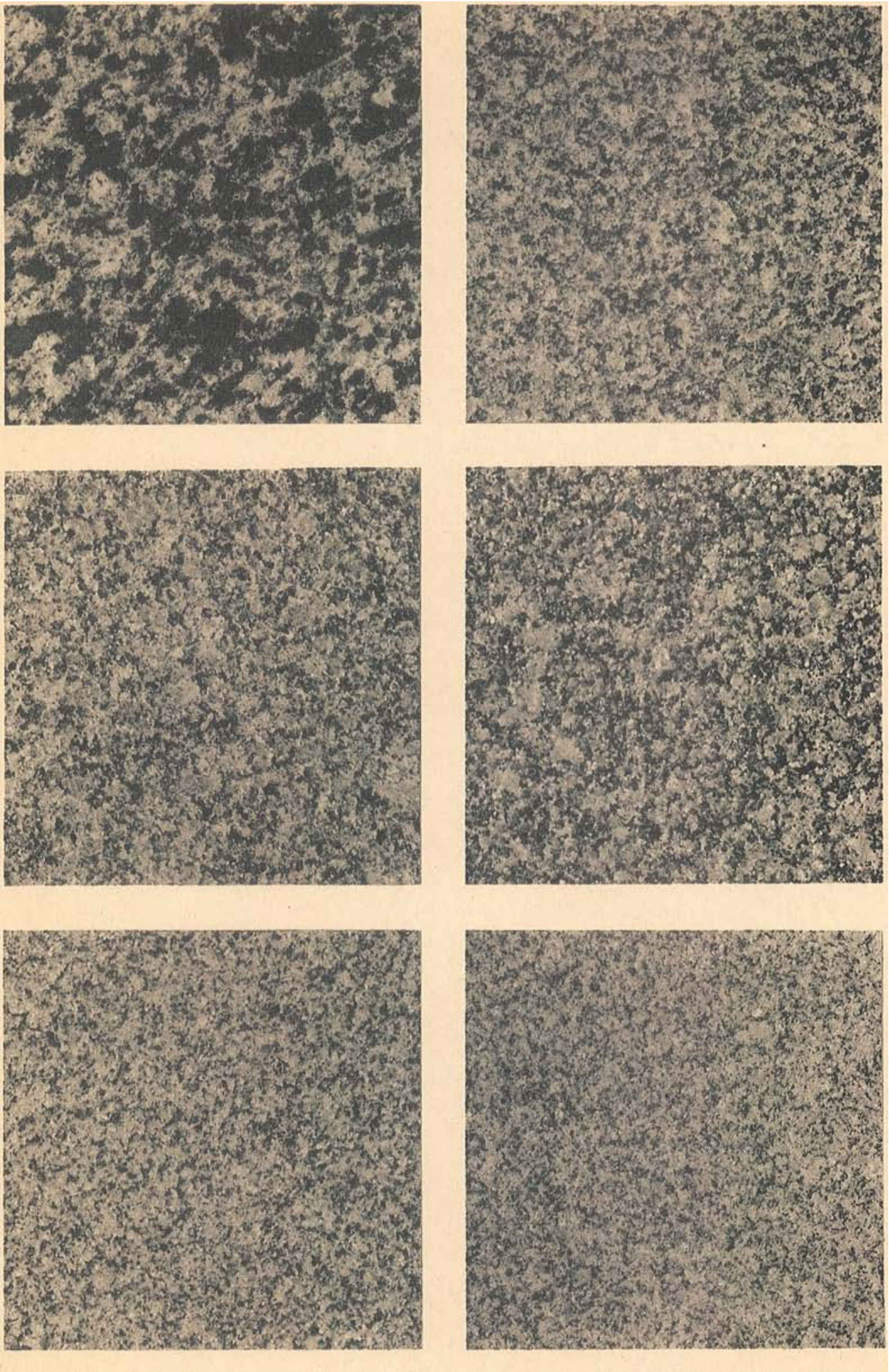
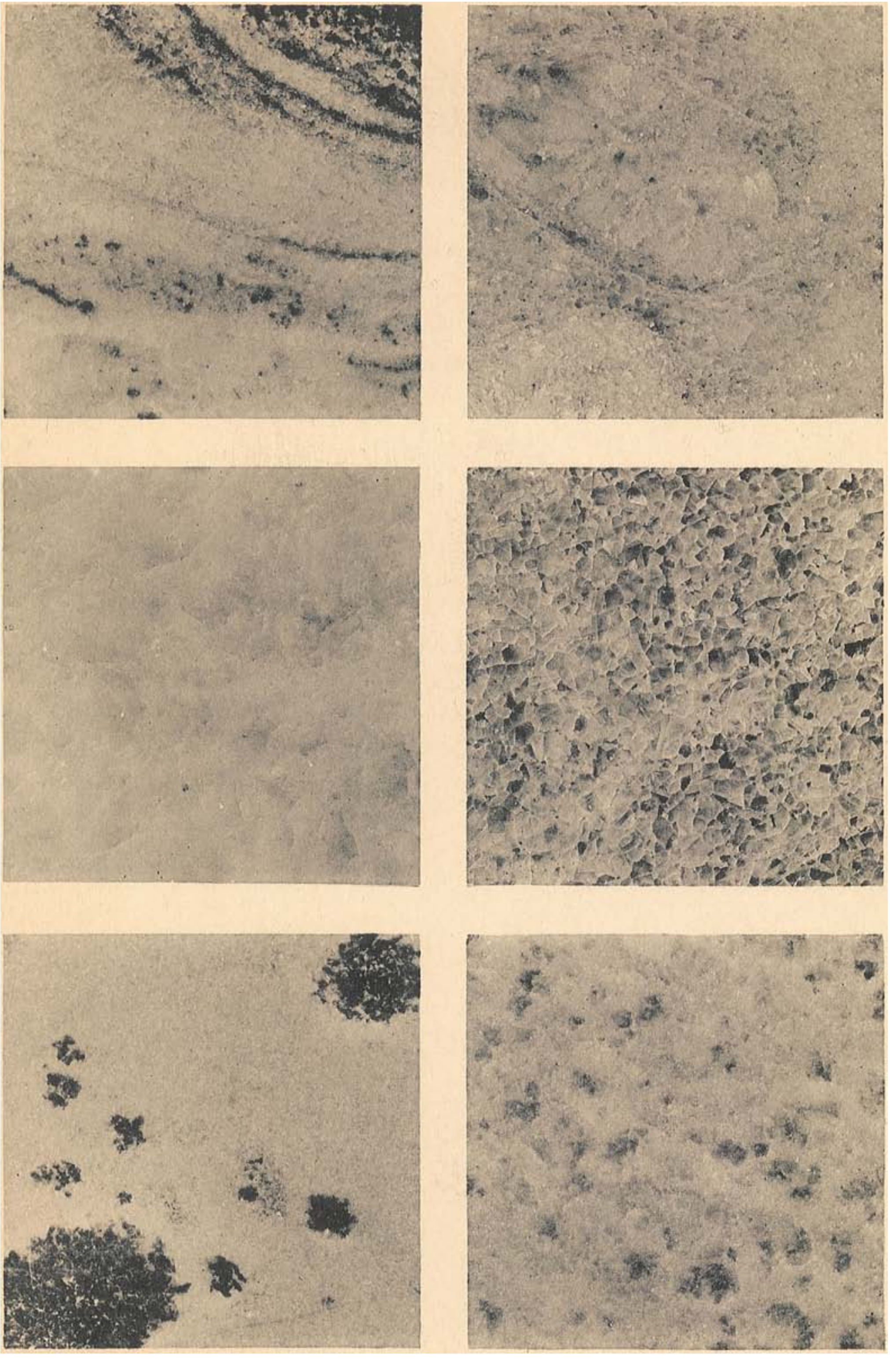


PLATE 4

Photographs of polished surfaces of gray granite, x1.

PLATE 5

Photographs of polished surfaces of pre-Cambrian marble, x1.



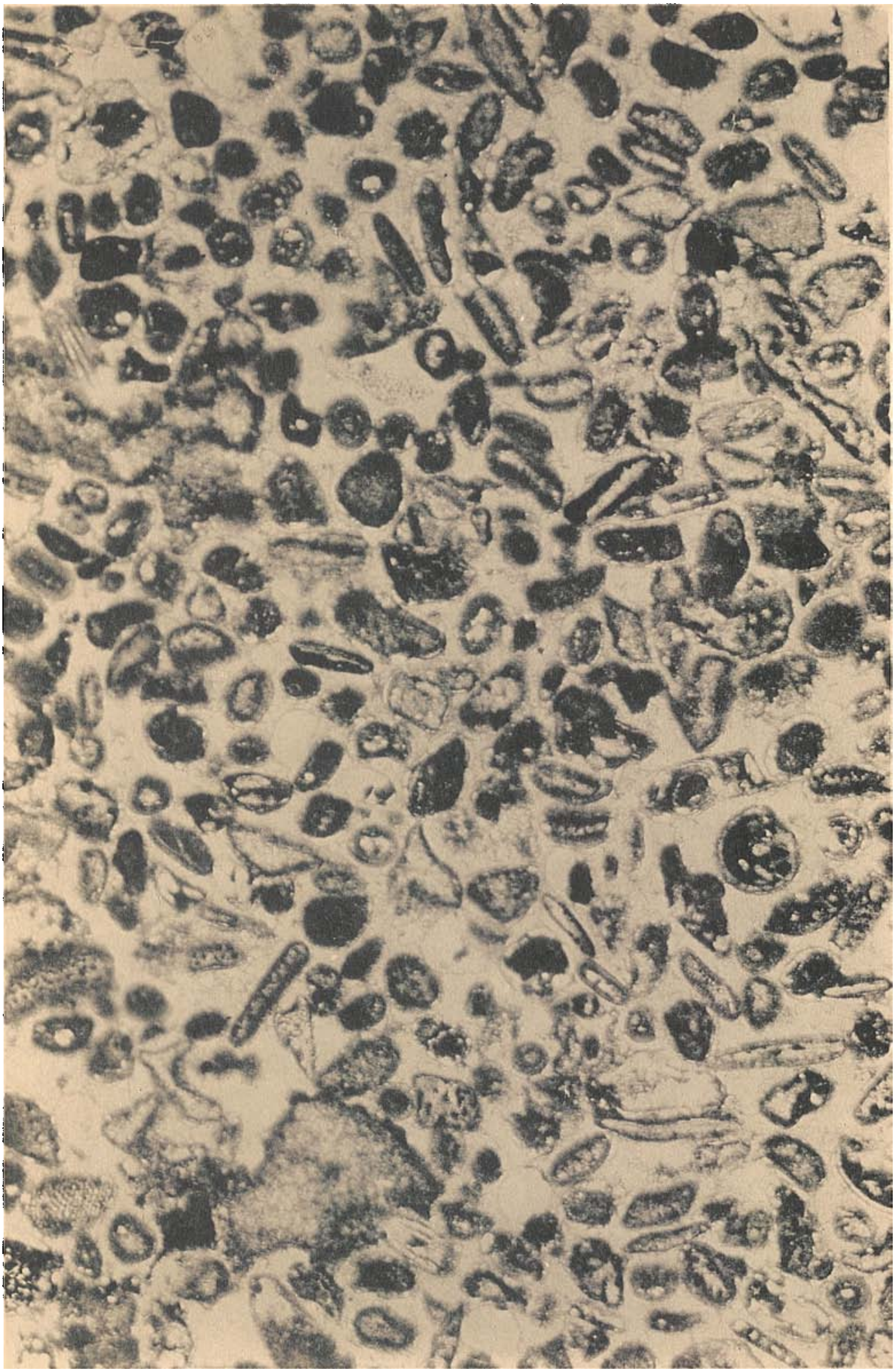


PLATE 6

INDEX

Map of central Texas showing building stone localities. The large hollow letters, overprinted in red, designate the county, and localities within each county are listed numerically. For example, Bu–43 is the 43rd building stone locality in Burnet County and is used throughout the publication to designate this particular deposit.